ECL 196

ENGINEERING CASE STUDY

FROM THE ELECTRIC POWER INDUSTRY

SPACE CONDITIONING SYSTEM

FOR

ELECTRONIC ASSOCIATES, INCORPORATED

B. VINCENT VISCOMI
LAFAYETTE COLLEGE

THE DIVISION OF ENGINEERING
Lafayette College, Easton, Pennsylvania

ENGINEERING CASE LIBRARY

ECL 196A

SPACE CONDITIONING SYSTEM FOR
ELECTRONIC ASSOCIATES, INCORPORATED

Part A

The Problem

The heating and cooling system for the Electronic Associates, Inc. administration building, in my opinion, represents nearly the ultimate in conservation of energy. We have tried to take advantage of every BTU generated in the system and utilize it efficiently rather than exhaust it to the atmosphere or to a spray pond or a cooling tower as is done in conventional systems. To my knowledge, this is the first fully-automated building of its kind to "go all the way" using heat-of-light, heat recovery and heat storage within an all-electric concept without special building design considerations or extra insulation. It was truly a challenge to our imaginations and we are confident this installation will influence future thinking by design engineers in the lighting, heating and air conditioning fields.

John F. Gruitt
Jersey Central Power
and Light Company

Written by B. Vincent Viscomi with the support of the Middle Atlantic Power Research Committee. Published by the Engineering Case Program with the support of the National Science Foundation.

INTRODUCTION

Jack Gruitt first "got wind" that Electronic Associates, Inc., was considering an expansion program in February, 1963. At that time Jack was the Industrial Representative in the Sales Department of Jersey Central Power and Light Company in Asbury Park, New Jersey. As such, he was anxious to contact customers early in the planning stages of their programs. In Jack's words, "Early entrance into a job assures us of being in on the 'ground floor' and greatly enhances our chances to exercise influence and guidance during the design stages." That same day, Jack contacted Mr. William Hennum of Electronic Associates, Inc., and made an appointment to assist him in planning his electrical needs.

Electronic Associates was founded in 1945 and is one of the leading developers and manufacturers of general purpose electronic analog computers. The company also designs and produces process control computers, electronic plotting equipment, laboratory instruments and, in 1962, introduced a hybrid digital-analog computer combining the strengths of the two computational devices.

Bill Hennum, as Corporate Facilities Engineer, was responsible for all plant engineering, construction, and real estate activities for the company. The new facility being planned was an administration building of approximately 95,000 square feet to be utilized for engineering, research laboratory, executive and general office functions. Bill hated to see energy wasted and was determined that the new facility would be an efficient user of energy.

A particular source of annoyance to him was the fact that most modern office buildings require heating and air conditioning <u>at the same time</u> during a major portion of the year. This will be discussed in more detail later but, basically, the inner core of a building must be air conditioned essentially the entire year, whereas the periphery of the building must be heated whenever the outer temperature drops below a certain value. With this in mind, he conducted a two-year study of the flow and temperature of the water in a creek running through the company property to determine its heating and cooling capability. He concluded that the stream would not be useful but he enjoyed the exercise.

Since EAI was located on the New Jersey shore in West Long Branch, Bill would often walk down to the beach, and as he watched the waves roll in he was awed by the beauty of nature's energy and, at the same time, mindful that it was also wasted energy.

When Jack and Bill first met, Jack inquired into the type of equipment to be used in the engineering and research facilities and offered some suggestions for lighting intensity levels in the various functional areas of the new building. Mr. Hennum agreed to the recommendations that ran between 100 and 200 foot-candles. During the course of the discussion, Jack asked Bill how he intended to heat the building. Bill answered, "If you're trying to sell me electrical resistance heating, forget it because it's too expensive! I'm interested in the most efficient owning and operating system and not appeals made to cleanliness, convenience, flexibility, or noiselessness." He continued, "Presently, we are considering various alternative conditioning systems such as oil or gas fired boilers plus conventional electrically-driven air conditioning systems. In addition, I'm intrigued by the total energy system in which we would use gas driven engines to drive generators to produce our electrical needs and use the waste heat for heating and air conditioning--air conditioning would be accomplished using an absorption system. If we consider the economics of heating only, I can buy #4 fuel oil at 8½¢ per gallon and at 70% boiler efficiency this represents approximately 12,000 BTU's for 1¢. (Mr. Hennum would not use #6 fuel oil, although cheaper, because it was high in sulphur content and would add considerable SO_2 to the atmosphere.) Natural gas is available at 9¢ per therm and considering boiler efficiency, this would be equivalent to about 8000 BTU's for 1¢. However, on a total energy basis, gas may still be attractive. With electricity, even at the lowest rate of 1¢ per KWH, using it for resistance heating and assuming 100% efficiency, I would be buying 3413 BTU's for a penny."

Jack got the message that it would be necessary for him to come up with an approach to electrical space conditioning that would be economically feasible, practical, and completely acceptable to Mr. Hennum. At this point Jack asked, "Mr. Hennum, since you are committed to good lighting, have you considered the possibility of utilizing the waste heat from the lights? New lighting fixtures are available which are slotted and are used to return room air to the cooling units. It has been estimated that light output would be increased 10 to 15% because the cooled fluorescent lamps would be operating near optimum temperature

conditions. In addition, the amount of circulated air would be reduced significantly and could reduce the costs of air handling equipment by 10-12%."

At this point Jack had exhausted his knowledge of the control of lighting heat, but he had captured the imagination of Mr. Hennum who said he was open to his suggestion. Jack Gruitt readily acknowledged his lack of additional information on this relatively new concept but said that he would be happy to consider the possibilities with him and determine if the concept had any merit for his new building. Mr. Hennum suggested he also contact the architect and consulting engineer.

CONTROLLING LIGHTING HEAT

After the meeting Jack decided, since he knew so little about the "heat-of-light" concept, the best place to become educated in a hurry was to consult with those who had been pioneering in this field. He contacted Day-Brite Lighting Company, one of the companies manufacturing the heat transfer type lighting fixtures, and was told they had laboratory facilities to demonstrate the concept. Basically, the facility is a room within a room where the inner room is used to simulate a portion of a building using the heat transfer lighting fixtures and the outer room simulates outdoor temperatures, with control from -20° to 120°F. If Jack would provide the necessary information, Day-Brite was willing and anxious to prepare a mock-up of an office module in the new EAI building. Jack extended an invitation to Mr. Hennum, Mr. Bernard Kellenyi, and Mr. Thomas Beers to visit Day-Brite's new thermal lab facility. Mr. Kellenyi was the architect and Mr. Beers, the consulting engineer for the EAI project. They all agreed to the visit and Mr. Kellenyi provided information on the dimensions of a typical office and the exterior design. The building is a steel frame structure with curtain wall panel and glass-type construction and a flat roof with two floors above grade and one below (see Appendix A, Figure 1A). The glass window area comprises approximately 23% of the total external wall. It was agreed a lighting level of 150 foot-candles would be used in the mock-up.

VISIT TO DAY-BRITE

Late in March, 1963, Jack and his three guests visited Day-Brite. Considerable time was spent on the technical discussions on the performance of the fixtures during both the cooling and heating seasons. The reduction in cooling

air flow resulting from the removal of heat from the fixtures was demonstrated--the air returns at a higher temperature, thus requiring less flow to remove the heat. When the ventilation air requirements were considered, a small amount of refrigeration was also saved. The above features may be demonstrated with the following calculations, assuming 100 square feet of floor space and a nine foot ceiling:

A. Maximum Sensible Heat Gain in Occupied Space With Conventional Lighting

From glass, wall transmission and solar	2500 BTU/hr
From people	250 BTU/hr
From business machines	200 BTU/hr
From lighting	2000 BTU/hr
Total	4950 BTU/hr

B. Maximum Sensible Heat in Occupied Space Using Heat Transfer Fixtures

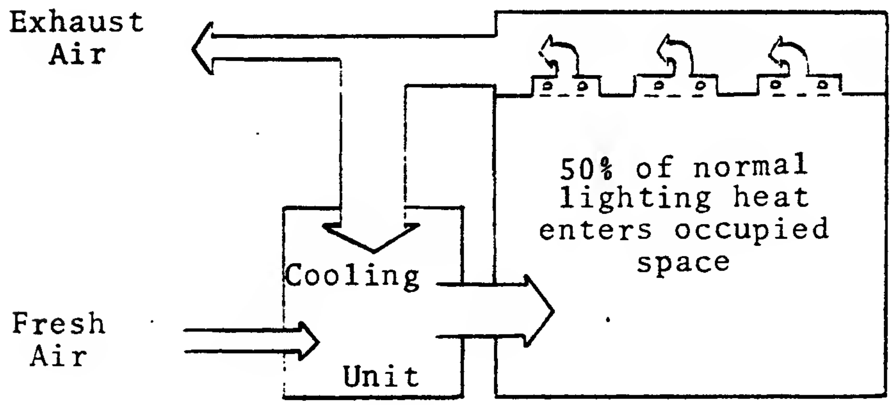
From glass, wall transmission and solar	2500 BTU/hr
From people	250 BTU/hr
From business machines	200 BTU/hr
From lighting (50% picked up by return air)	1000 BTU/hr
Total	3950 BTU/hr

C. If the room is kept at 75°F and the cool air entering is kept at 55°F, then the air flow required to balance the heat may be calculated from the formula:

Heat gain = 1.08 x C.F.M. x Temp Rise

Using this formula the air flow required for the conventional system is approximately 230 CFM or 15 air changes per hour, whereas the air flow with the heat transfer fixtures is 180 CFM or 12 changes per hour.

D. The return air temperature for a conventional system would be very nearly 75°F; with the heat transfer fixtures, the return air temperature may be 8-10°F higher. A certain portion of this air is exhausted and replaced by fresh ventilation air. Exhausting air at a higher temperature will reduce the refrigeration requirements. A schematic is shown below:



As informative as the trip seemed to be, it became quite obvious that the "heat-of-light" system had not progressed to the point where it could be wrapped up as a single package for any given building. There still remained many unanswered questions, such as, how to control the heat once it passed through the lighting fixtures, whether all fixtures should be used for air return, or whether some should be used for air supply. Although Day-Brite did not have all the answers, the group was still determined to pursue the matter further and consult other authorities in the field of air handling and control.

VISIT TO BARBER-COLMAN COMPANY

Shortly after he returned from St. Louis, Jack contracted the Barber-Colman Company and solicited their help in tackling the problems of air handling and control. The Barber-Colman Company engineers had air handling equipment designed for heat-of-light systems and felt it was applicable to the EAI building. In addition, they had joined with Day-Brite in offering a package system for air supply and return. On June 17, several sales engineers visited EAI and presented their system. A letter from Mr. Robert B. Dailey, Executive Sales Director for Barber-Colman, to Mr. William Hennum summarizing the advantages of the Barber-Colman system is included in Appendix A as Exhibit 1A. Included also is

an article describing the Barber-Colman system entitled "New Economy for Interior Zones." In order to confirm the design parameters, Barber-Colman Company prepared a second mock-up of the building in their laboratory located in Rockford, Illinois. In August, 1963, Messrs. Hennum, Kellenyi, Beers, and Gruitt visited the Rockford plant and observed the demonstration tests. The demonstrations were carried out successfully, and the members of the visiting group were well satisfied with the results, which answered many questions they had had previously.

By this time, all parties concerned were quite enthusiastic about the heat-of-light system, and Mr. Beers was given the go-ahead to proceed with the selection of the compressor equipment and heat recovery phase of the job. As Jack looked back on this project he observed, "We should bear in mind that every phase of this concept had to be thoroughly explored since there were no other industrial applications of this type that we could point to as a precedent. The type of experimenting and exploration we were doing was not to be found in a textbook. The closest approach to the system we were considering was in an installation at the Kimberly High School in Kimberly, Wisconsin. This design utilized heat extracted from a source well and discharged to a deep well. We obtained whatever information we could on this installation, but found that we would have to depart radically from the design as it was incorporated in the Kimberly High School installation."

APPENDIX A

FRONT VIEW OF EAI PLANT. HEAT-OF-LIGHT RECOVERY SYSTEM INSTALLED IN ADMINISTRATION BUILDING RIGHT OF PHOTO.

Figure 1A

DATA SHEET

ECL 196A

General Description:

Area, 94,500 sq ft; volume, 897.750 cu ft; number of floors, 3; number of occupants, 450; number of rooms, 285 movable partitions; major types, executive and general offices, conference rooms, research and testing laboratories, drafting and engineering, cafeteria.

Construction Details:

(1) Glass (single): ¼ in. plate glass
(2) Exterior Walls: panel curtain walls, 1 in. insulation; U-factor .22
(3) Roof or Ceilings: 5 ply built-up with 1½ in. poured gypsum on 1 in. fiberglass base; U-factor, .16
(4) Floors: 4½ in. reinforced concrete slab over Tuf-cor.
(5) Exposed Wall Area: 32,216 sq ft; Glass Area: 7,313 sq ft

Heating:

Heat loss Btuh, 2,450 MBH; normal degree days, 5320; ventilation requirements, 14,500 cfm normal, 22,000 cfm with cafeteria in operation; design conditions, O F and 70 F.

Cooling:

Heat gain Btuh, 5,400 MBH; ventilation requirements, 14,500 cfm normal, 22,000 cfm with cafeteria in operation; design conditions, 95 F dry bulb, 78 F wet bulb, outdoor, 78 F dry bulb, 50 percent R.H., indoor.

Lighting:

Level in footcandles, 125 fc; level in watts/sq ft, 4 to 7.0W/sq ft; type, 2 ft x 4 ft recessed, 4 lamp R.S.

Heating and Cooling System:

Storage reservoir heat sink, heat of light, heat recovery, 4 pipe chilled and hot water to fan coil units with single duct jetronic induction units and controls, heat transfer lighting fixtures, centrifugal and reciprocal compressor chillers.

Installed Cost (Administration Building):

General work (all other)	$8.55/sq ft	$ 807,900
Heating, ventilating & air conditioning (including emergency generation)	2.75/sq ft	259,900
Electrical (includes lighting)	1.70/sq ft	160,700
Plumbing (sanitary & potable)	.50/sq ft	47,300
Total	$13.50/sq ft	$1,275,800

BARBER-COLMAN COMPANY
ROCKFORD, ILLINOIS, U. S. A.

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AIR DISTRIBUTION PRODUCTS
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AUTOMATIC CONTROLS
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ADDRESS REPLY TO
207 EAST 37TH STREET
NEW YORK 16, N. Y.
MURRAY HILL 7-0010

June 18, 1963

Mr. William Hennum
Plant Engineer
Electronic Associates, Inc.
Long Branch Avenue
Long Branch, New Jersey

Subject: The Barber-Colman "Heat of Light" System

Gentlemen:

At the conclusion of our meeting on June 17 it was suggested we outline the advantages of the Barber-Colman "Heat of Light" system as they apply directly to your new office building.

This system was developed in order to solve two problems created by higher lighting levels. As foot candles are increased there is a corresponding increase in the heat generated by the lighting fixtures making it necessary to design a system to first, reduce the amount of heat entering the occupied space; second, to utilize this heat for both zone tempering purposes and to heat the skin of the building during the winter period.

The first component of this system is a heat extractor type lighting fixture. This fixture is provided with a return air inlet at one end and an exhaust opening into the ceiling cavity at the opposite end. This permits the return air to pass across the entire length of the lamps picking up the heat generated and exhausting it into the ceiling cavity. By this means, an average of 82% of the heat generated is exhausted into the ceiling cavity and kept out of the occupied space. Unfortunately, some of this heat re-enters the space through the ceiling and by coming in contact with cold diffuser and duct surfaces.

If every light fixture is provided with extractor accessories, 65% of the heat generated by lighting is kept out of the occupied space. As a consequence, the conditioned air necessary to overcome lighting heat can be reduced by 65% with a corresponding reduction in the size of cold air supply ducts, fan sizes and fan horsepower.

As the temperature of the air within the ceiling cavity is now considerably higher than the room temperature, it becomes a suitable heat source for tempering purposes. The Heat of Light induction unit is installed in the ceiling cavity directly over, or close to the zone

SUBSIDIARIES
BARBER-COLMAN OF CANADA, LTD. TORONTO, ONTARIO, CANADA
SHEFFIELD DOORS INC. SHEFFIELD, ILLINOIS
AFFILIATES
BARBER AND COLMAN, LTD. BROOKLAND, ENGLAND
BARBER AND COLMAN, GMBH MUNICH, WEST GERMANY

BARBER-COLMAN COMPANY

being served. By means of a simple set of dampers on the primary air inlet and induced air inlets, the classic air induction principal is used to mix primary air with cavity air. Up to 50% of the hot cavity air can be induced into the unit with a corresponding reduction of primary air yet with no change in the total air quantity delivered to the space. With the constant volume of air being delivered, more than adequate temperature variations are available to take care of variations in occupancy, appliance usage and solar requirements.

The use of the Heat of Light induction unit eliminates the need for zone reheat coils or hot air ducting for a dual duct system.

The hot ceiling cavity air, not used for induction purposes, is returned to the mechanical equipment room where it can be re-circulated directly to the skin system to partially fulfill the heating requirements of the building or passed over the system cooling coils to be concentrated by the refrigeration equipment into a higher heating level. This higher heating level may be used either directly to raise the temperature of the air going to the skin system, or diverted to the storage system to fulfill non-occupied or emergency requirements.

In summary:- The "Heat of Light" system:

1. prevents 65% of the heat generated from lighting from entering the occupied space;

2. consequently, reduces the amount of conditioned air required for the space;

3. uses the hot ceiling cavity air for local reheat purposes without the need of additional duct work;

4. uses the hot return air, either directly to heat the skin of the building, or indirectly to improve the coefficient of performance of the refrigeration equipment.

We sincerely appreciate the opportunity for having been able to present the advantages of the Barber-Colman "Heat of Light" system to you and appreciate, too, your sincere consideration. Should you have any further questions please be assured that we will gladly make every effort to answer them.

Very truly yours,

Robert B. Darling
Executive Sales Director

RBD/jg
Enclosure

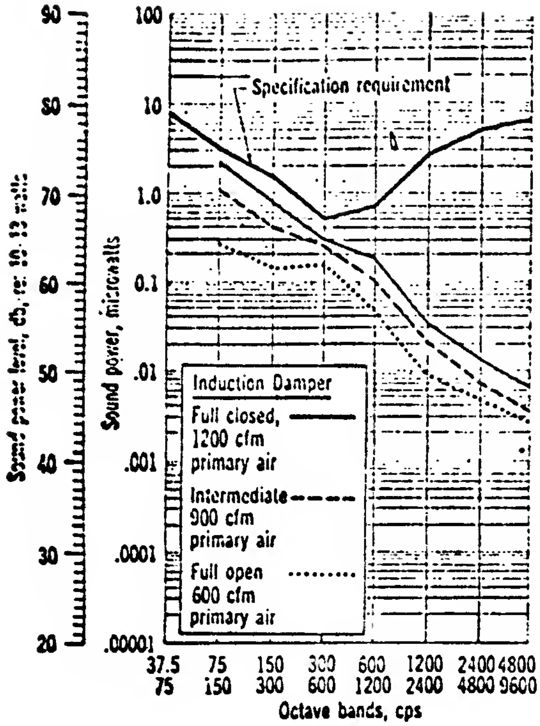


Fig. 6. Sound power emitted by induction unit through induction opening and radiated by unit walls.

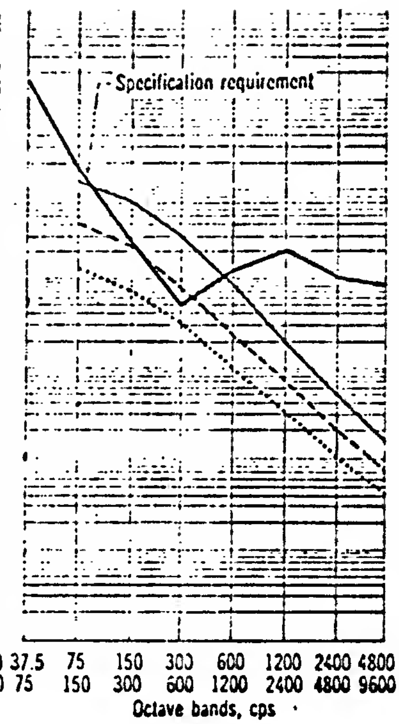


Fig. 7. Sound power emitted through discharge opening with 15 ft of unlined duct proved unsatisfactory.

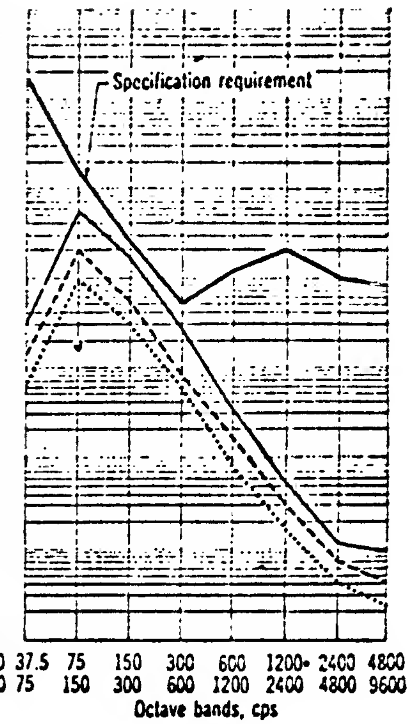


Fig. 8. Addition of 8 ft of 1-inch, 1½-lb acoustical lining to duct brings sound power levels down.

on an unlined duct, illustrated in Fig. 7, proved unsatisfactory; however, the addition of a minimum length acoustic liner brought the sound power readings into acceptable levels as illustrated in Fig. 8.

Additional Design Considerations

Several other design considerations must be analyzed so that they may complement induction box usage: inlet vanes, induction box balancing dampers, and the air filtration system.

As it is essential to maintain constant mixed-air quantities supplied to the occupied spaces, the primary supply air quantity must vary in inverse proportion to the change in the induction ratio. Utilization of inlet vane assemblies on the supply and return-air fans, with the vane settings positioned by supply air, must be as required to maintain induction box constant volume discharge conditions. Because air velocity pressure measurements, to be accurate, must be made in a straight supply duct section prior to the first branch take-off, ducts in this system do not change in size or direction for a minimum of 10 ft before or after the point of measurement.

The lineal distance from the supply fan to each induction box of necessity varies on the supply runs. Therefore, to obtain the desired inlet static pressure at each box, the design must provide for the proper pressure at the inlet box on the *end* of the run. Manual balancing dampers at all other boxes closer to the fan compensate for variations in pressure loss so that all boxes may operate on the same design basis.

Central fan station filtration assemblies are now more important than usual as, unlike the case in conventional systems, a portion of the re-usable air does *not* pass through the filter system on each cycle. The induction box does *not* have an individual filter in each assembly. Therefore, the initial installation must be designed with a higher particle removal efficiency than normal on the central station equipment.

Applications

The induction box concept, as applied to the General Office Building of the Los Angeles Department of Water and Power, accounts for 580 zones and 840,000 cfm out of a system total capacity of 850 zones and 1,300,000 cfm. The remaining zones utilize standard high-velocity, double-duct units. These are the peripheral and top floor areas.

Incorporating the minimum performance qualities as outlined, the induction box herein described can be applied immediately to multi-story building interior zones. The year-round school, with its lack of glass, higher lighting levels, and the new module approach, will be a natural application for this unit. Application to industrial complexes, banks and research centers, all of which are following the trend toward higher lighting intensities, is but a matter of time.

Participating in the design for the City of Los Angeles Department of Water and Power were F. M. Ivanick and K. O. Cartwright, and for Albert C. Martin and Associates, in addition to the author, were C. S. Perkins, head of Mechanical Department and Mechanical Design concepts; Horace Yeh, refrigeration design; and R. M. Steffens, plumbing design.

heavily on client funding and manufacturing research and development.

Competitive bids received from the manufacturers on the testing and development specification were evaluated jointly with the client, Los Angeles Department of Water and Power. The evaluation resulted in the acceptance of the technical assistance offered by a manufacturer in developing the design concepts. The testing and development procedures resulted not only in a complete affirmation of the design theories, but also the *single inlet induction box* as described herein.

How the New Box Works

The single inlet induction box, located in the return-air plenum cavity and receiving only a primary cold-air supply, can satisfactorily induce a portion of warm plenum air into the box and thus temper the primary air as required for zone conditions. Induction ratios outlined in Table 1 indicate that, with a primary supply-air temperature of 55 F and a return-air plenum temperature of 85 F, the discharge mixed-air temperature varies between 55 and 70 F for induction ratios of 0-50% of total box air capacity.

An interior space zone thermostat controls the functioning of the box. On a thermostatic call for full cooling, the induction dampers are fully closed and the induction box handles only primary cold air. As the thermostat calls for reduced cooling, the induction dampers proportion toward the full open position, thereby inducing warm air from the ceiling return plenum into the box and tempering the box discharge supply temperature. When the thermostat calls for additional cooling, the reverse operational sequence takes place. As induced air is increased or decreased the primary air, controlled by supply fan inlet vanes, varies appropriately to maintain a constant box air discharge.

Construction and Cost Considerations

The induction box casing is made from 20-gage cold rolled steel and is lined on the interior surface with 1-inch thick acoustic insulation. The insulation installation has been designed to withstand the pressures of velocities up to 5,000 ft per min, and all insulation surfaces exposed to the air stream have been treated with a plastic coating to eliminate air erosion. Induction and by-pass damped blades are fitted with rubber gasket seals to prevent air leakage when the dampers are in a closed position. Blades are formed from 16-gage steel to provide rigidity and are mounted on stainless steel shafts that rotate on nylon bearings. All damper operating linkage is mounted outside the box so that minor adjustments can be made to the linkage without disturbing the box.

The induction box eliminates the necessity of a hot duct in a conventional high-velocity, double-duct system. Elimination of the hot duct and such attendant system components as sheet metal, hot water heating coils, hot water piping, sheet metal insulation, piping insulation, and temperature controls, in addition to the size reduction of building heat generating and distribution equipment, resulted in the $330,000 construction cost savings.

Table 1—Induction Box Characteristics

Per cent induction	0	10	20	30	40	50
Mixed air temperature, F	55	58	61	64	67	70

Testing and Development

Specifications for testing and development separated performance requirements into two main categories: *air flow* and *sound control*. The air flow category was subdivided into tests for volume control, induction, and leakage; while the sound control category was subdivided into tests for sound power levels of noise emitted through the induction openings and radiated by casing walls, and sound power levels of noise emitted through the discharge opening.

In compliance with the specification and its testing program, a full scale, middle range, induction box, having a nominal capacity of 1200 cfm and overall dimensions of 36 inches long by 25 inches wide by 10 inches high with a 10-inch diameter, 16-inch long, inlet cone, was developed as the test unit. The induction box was attached to a 55-F cold air supply system capable of producing the required air flow at inlet pressures necessary to fulfill the test requirements. Return plenum induction air was maintained at 85 F. A downstream 20 × 10 inch, 12-ft long, duct system with 1-inch interior acoustic lining was used to measure total air flow and discharge opening sound levels. Acoustically treated balancing dampers were installed in this duct to create a 0.15-inch of water downstream pressure resistance. Figure 2 indicates the test installation, delineating the necessary orifices, pressure gages, and temperature measuring devices to measure primary air flow, pressure, and temperature; induced air flow, pressure and temperature; as well as mixed air flow pressure and temperature.

Air Flow Tests

Air flow tests were made for volume control, induction and leakage requirements from zero to maximum induced air flow at induction box inlet pressures of

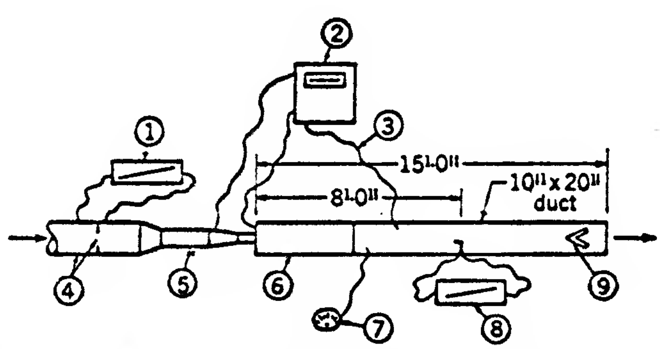


Fig. 2. New induction box under test: 1. Pitot tube and slope gage for primary air flow measurement. 2. Temperature recorder. 3. Thermocouples measure primary, induced, and mixed-air temperatures. 4. 12-inch dia duct with 9-inch orifice. 5. 10-inch dia. 6. Single-inlet mixing unit. 7. Static pressure gage. 8. Pitot tube and slope gage for velocity pressure measurement. 9. Acoustically covered damper to maintain 0.15 inch w.g. downstream resistance.

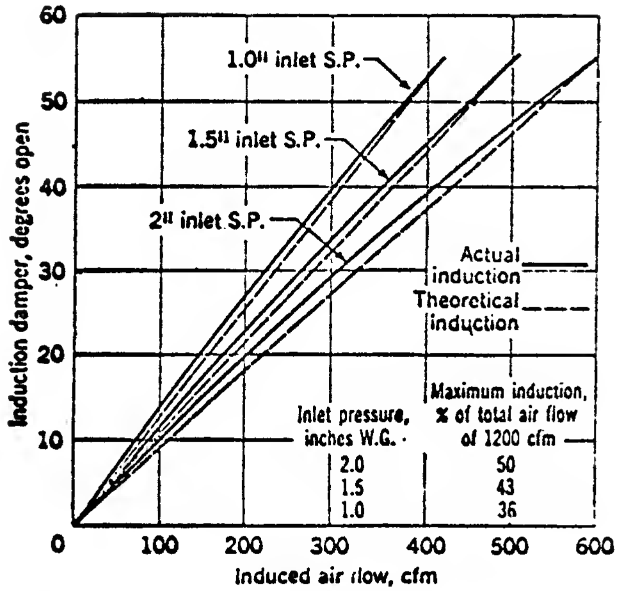


Fig. 3. Response of induced air flow to change in damper settings is practically linear at the three required inlet static pressures.

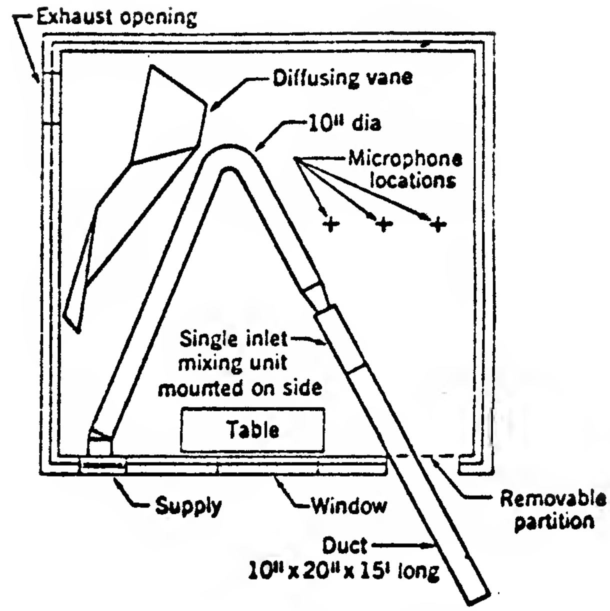


Fig. 4. Plan of reverberant room, showing test for sound power levels of induction inlets and unit radiated noise.

2, 1.5 and 1.0 inches of water. Flow properties of the induced air with respect to degree opening of the induction damper, along with the relationship of the maximum induced air as a percentage flow are illustrated in Fig. 3. Box induction, with respect to total air, from 0 to 50%, results in a curve with linear characteristics for damper movement from full-closed to full-open position.

Total discharge-air volume of the induction box did not vary more than ±3% in conjunction with the movement of the induction damper from full-closed to full-open, thus depicting accurate box volume control as the induced air quantities varied from 0-50% of total box quantity, at a constant inlet pressure of 2 inches throughout the movement of the dampers. Leakage through the induction opening, with the induction dampers fully closed, did not exceed 1.5% of primary air flow.

Sound Control Tests

Sound control tests were made with respect to sound emitted through induction openings and radiated by the unit casing, and sound emitted through the discharge opening on air flow tests with box inlet pressures of 2, 1.5, and 1.0 inches of water. Figure 4 indicated the reverberant room test set up for measuring sound power levels of induction openings and unit casing radiation, while Fig. 5 indicates the test set up for measuring sound power levels through the discharge opening. (The reverberant room used met accepted acoustical test standards, being completely soundproofed and isolated from the surrounding building structures. A diffusing vane surface that improves the sound diffusion qualities of the room at low frequencies had been installed along the wall. The sound tests were made using a total discharge air flow of 1200 cfm, box inlet pressures of 2, 1.5, and 1.0 inches of water, and induction damper settings of full-open, half-open, and full-closed. Sound power levels for the 2-inch pressure range, as graphed in Fig. 6, indicates that the unit noise emitted is well within specification requirements. Discharge sound tests for the 2-inch pressure range as first obtained

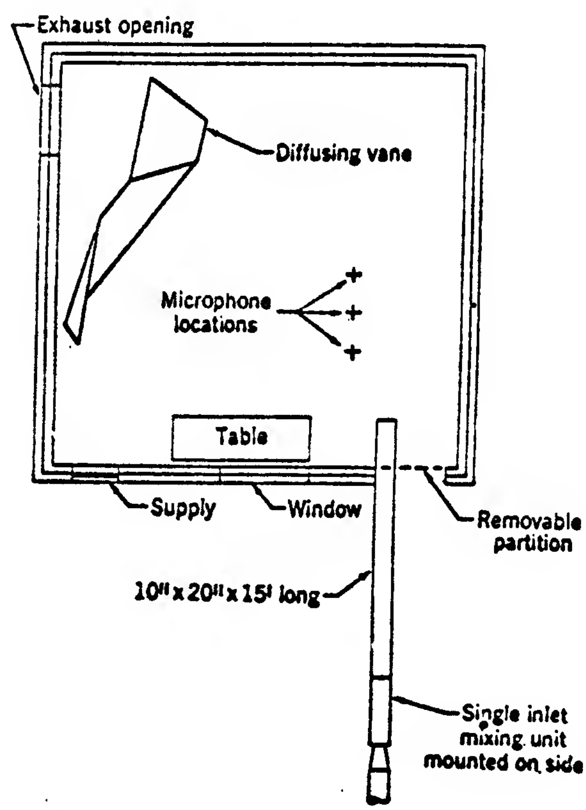


Fig. 5. Plan of reverberant room, showing test for sound power levels at end of 15-ft discharge duct work.

new economy for INTERIOR ZONES

ROBERT F. COYNE
Project Engineer
Albert C. Martin and Associates
Architects and Engineers, Los Angeles

A new type induction box applied to interior-zone air conditioning saved hundreds of thousands of dollars in a Los Angeles building.

A FUNDAMENTAL DESIGN CONCEPT conceived and developed for the new General Office Building of the Los Angeles Department of Water and Power has resulted in a $330,000 savings from the construction cost of a conventional interior-zone air conditioning system. This concept has provided a bedrock foundation for an engineering breakthrough in air conditioning system design for interior zones of many industrial and commercial buildings utilizing the higher lighting levels recommended by the Illuminating Engineering Society. With this breakthrough, the engineer has now been provided with another design tool, so that he can continue to evaluate each air conditioning application in terms of the best solution to the problem.

Basis of Design

Assuming that solar loads and outdoor ambient temperature variations are compensated for by adequate solar protection and peripheral skin zones, all floor areas of a building structure, other than the top floor, which requires special roof surface treatment, are on a constant, year-round cooling cycle. Interior sensible heat gain from people, machines, electrical devices, and the lighting system, constitute the main air conditioning load on the interior zones. On an "all air" conditioning system, air supply temperatures, as required to offset heat gain and maintain desired occupancy conditions, vary uniformly within the cooling range dry-bulb supply temperatures of 55 to 70 F.

Heat from lighting at levels of 50 to 60 foot-candles accounts for approximately 65% of the internal load and approximately 35% of the total air conditioning load in the average office building. With the new Illuminating Engineering Society lighting level recommendations, average intensity jumps to more than 115 foot-candles, with even higher average levels predicted for the near future. The immediate result is an increase, in percentage of total air conditioning load attributed to lighting, from 35% to more than 55%. This increase in internal sensible load results in the formation of a built-in thermal heat sink that can considerably reduce the requirements of the building steam or hot water heating system.

The heat sink is greatly complicated and concentrated since the advent of the combination supply-and/or return-air lighting luminaire, as illustrated in

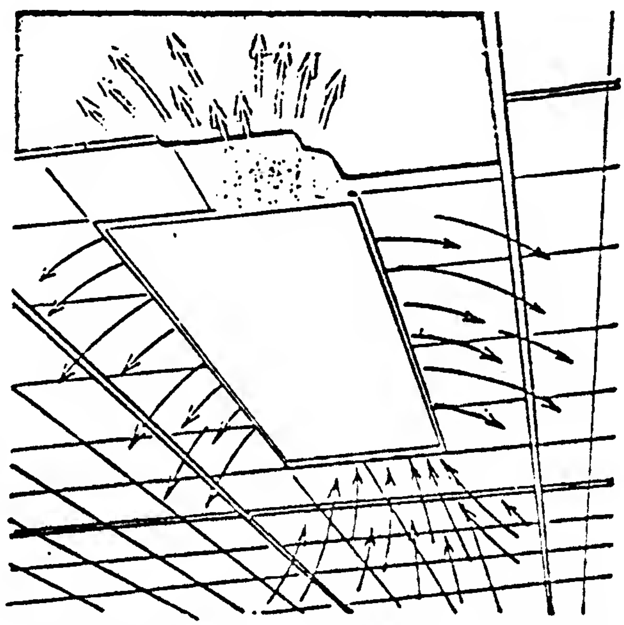


Fig. 1. Combination supply and return air and lighting luminaire.

Fig. 1. This unit immediately diverts a large portion of the developed lighting heat load from the occupied space to the return-air plenum cavity above the ceiling by transferring this heat to the return-air stream passing through the luminaire housing in the form of a minimum 10-F air temperature rise.

Search for a New System

An evaluation study of existing types of systems and equipment available in the air conditioning industry led to the conclusion that a more reliable and efficient method was needed to best utilize the merits of the thermal heat balance offered by the heat sink. Review of this evaluation indicated that a new and revolutionary design criteria was needed. Therefore, a concise testing and development specification, and program, was conceived and submitted to nation-wide manufacturers.

Many times, when engineers have development ideas for ingenious systems, they lack development funds and facilities to evaluate these ideas. Private and educational laboratories are at a premium and, in general, are not available, nor do they have the facilities for researching the systems that apply to the building industry. Therefore, the engineer must lean

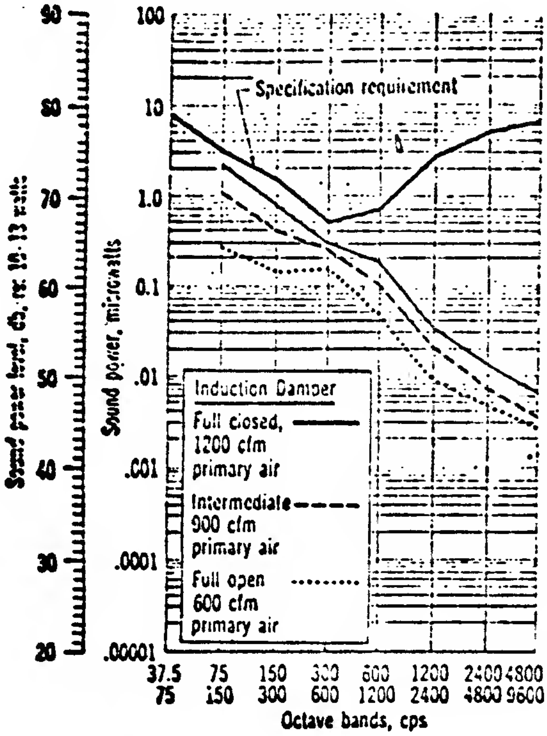


Fig. 6. Sound power emitted by induction unit through induction opening and radiated by unit walls.

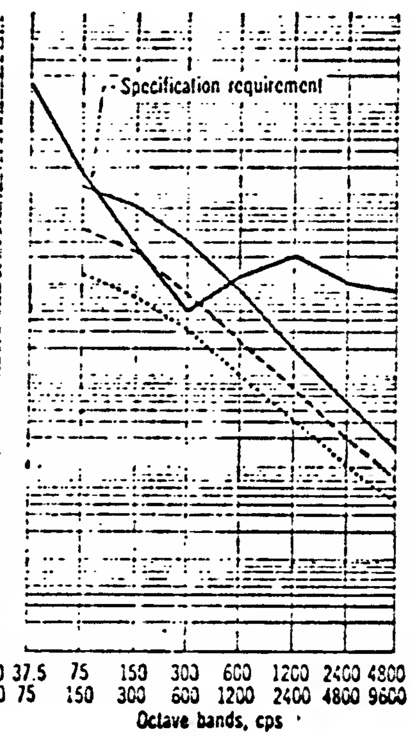


Fig. 7. Sound power emitted through discharge opening with 15 ft of unlined duct proved unsatisfactory.

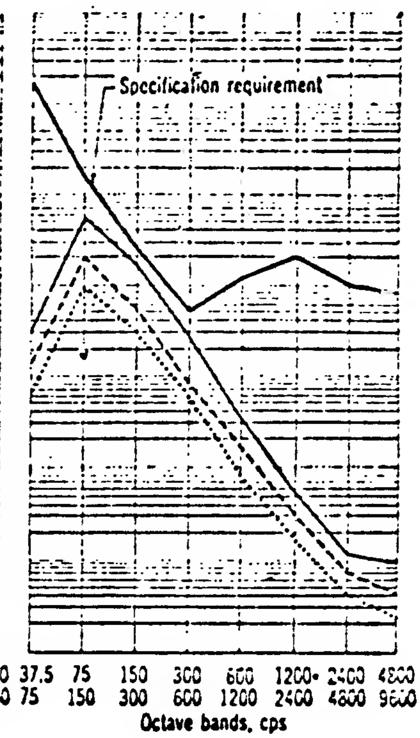


Fig. 8. Addition of 8 ft of 1-inch, 1½-lb acoustical lining to duct brings sound power levels down.

on an unlined duct, illustrated in Fig. 7, proved unsatisfactory; however, the addition of a minimum length acoustic liner brought the sound power readings into acceptable levels as illustrated in Fig. 8.

Additional Design Considerations

Several other design considerations must be analyzed so that they may complement induction box usage: inlet vanes, induction box balancing dampers, and the air filtration system.

As it is essential to maintain constant mixed-air quantities supplied to the occupied spaces, the primary supply air quantity must vary in inverse proportion to the change in the induction ratio. Utilization of inlet vane assemblies on the supply and return-air fans, with the vane settings positioned by supply air, must be as required to maintain induction box constant volume discharge conditions. Because air velocity pressure measurements, to be accurate, must be made in a straight supply duct section prior to the first branch take-off, ducts in this system do not change in size or direction for a minimum of 10 ft before or after the point of measurement.

The lineal distance from the supply fan to each induction box of necessity varies on the supply runs. Therefore, to obtain the desired inlet static pressure at each box, the design must provide for the proper pressure at the inlet box on the *end* of the run. Manual balancing dampers at all other boxes closer to the fan compensate for variations in pressure loss so that all boxes may operate on the same design basis.

Central fan station filtration assemblies are now more important than usual as, unlike the case in conventional systems, a portion of the re-usable air does *not* pass through the filter system on each cycle. The induction box does *not* have an individual filter in each assembly. Therefore, the initial installation must be designed with a higher particle removal efficiency than normal on the central station equipment.

Applications

The induction box concept, as applied to the General Office Building of the Los Angeles Department of Water and Power, accounts for 580 zones and 840,000 cfm out of a system total capacity of 850 zones and 1,300,000 cfm. The remaining zones utilize standard high-velocity, double-duct units. These are the peripheral and top floor areas.

Incorporating the minimum performance qualities as outlined, the induction box herein described can be applied immediately to multi-story building interior zones. The year-round school, with its lack of glass, higher lighting levels, and the new module approach, will be a natural application for this unit. Application to industrial complexes, banks and research centers, all of which are following the trend toward higher lighting intensities, is but a matter of time.

Participating in the design for the City of Los Angeles Department of Water and Power were F. M. Ivanick and K. O. Cartwright, and for Albert C. Martin and Associates, in addition to the author, were C. S. Perkins, head of Mechanical Department and Mechanical Design concepts; Horace Yeh, refrigeration design; and R. M. Steffens, plumbing design.

ECL 196B

Engineering Case Library

SPACE CONDITIONING SYSTEM FOR ELECTRONIC ASSOCIATES, INCORPORATED

Part B

The Solution

ENGINEERING CONSIDERATIONS

Tom Beers, as consulting engineer on the EAI administration building, was responsible for the mechanical design. He considered his function to be, "to provide good environmental climate, i.e., lighting, heating, ventilation and air conditioning, at the most economical operating cost consistent with reasonable capital investment." Some of Tom's clients look for low capital costs and are indifferent to operating costs, but Bill Hennum was definitely looking for the most efficient owning and operating system.

Tom's attitude toward the heat-of-light concept was that he did not object to pioneering as long as it was not at someone else's expense. He was interested in designing a reliable unit, not just a tribute to science. He began by calculating internal heat gains and building heat losses as a function of outside temperature. Consistent with most modern office buildings, the lighting load represents the major heat gain. In addition, heat is released by occupants, computer equipment on test, other office equipment as well as by fan motors and pumps supplying conditioned air to the building. This high internal heat gain increases air conditioning loads during the cooling season but is normally disregarded when designing the heating system. The basic decision made in the EAI building was to install a system that would take every advantage of internal heat load.

With this objective in mind, Tom calculated the BTU gain from lights and estimated the BTU gain from the occupants, fans, pumps and compressors. In addition to the building heat gain, a potential source of BTU's is the heat content of exhaust air which must be rejected from the building. On a design day, which is 0^{o}F in New Jersey, the amount of heat rejected in the exhaust air comes out to be approximately 650,000 BTU/hr. Tom met with Bill Hennum and they agreed this heat should be utilized.

Their solution was rather simple and inexpensive. The fresh air intake duct would include a cooling coil for dehumidification of the incoming air during the summer months and this coil could also be used for heating the incoming air during the heating season. All that was required was to place a coil in the exhaust duct and run the necessary

pipework. During the heating season an ethylene glycal solution would be circulated to extract heat from the exhaust air and reject heat to the incoming air. After draining the ethylene glycal solution, the coil in the intake duct would be used as a dehumidifying coil in the summer.

Combining all of the heat gains, assuming a 70% recovery from the exhaust air, Tom's calculations showed that when the building is occupied, heat input balances heat loss at about 11°F. (The curves are shown in Appendix B, Figure 1B.) Thus it is evident that, at any point above 11°F, there is an excess of heat over the building requirements during occupied hours. However, the heat is not necessarily released at the location where it is needed. For example, an internal room on the first floor, surrounded by other spaces maintained at the same temperature both winter and summer, would require <u>cooling</u> at approximately the same rate throughout all seasons. Rooms on the exterior would require more heat than would be gained from lights, and so forth, in the winter seasons.

Consequently, at temperatures above 11°F the problem becomes a matter of heat distribution, or the pumping of heat from one location to another, rather than heat generation. The solution to this problem fits in very conveniently with a chilled water mechanical refrigeration system when it is operated in the conventional manner to cool overheated spaces, mainly interior rooms, and utilizing the hot condenser water to heat the underheated spaces, mainly exterior spaces. In Tom Beers words, "You could go down and stencil on the refrigeration equipment 'THIS IS A HEATING MACHINE' and as a byproduct you would get cooling."

An alternative solution would be to use "free cooling" for the interior spaces and conventional heating for the periphery. Free cooling is the use of outside air, weather permitting, to cool the interior rooms. Tom's calculations indicated that the cost of fans, additional and larger ducts plus the cost of heating the outside air during low temperature periods when added to the cost of conventional heating of the periphery of the building would be higher than the proposed system.

The discussion so far has considered only the periods when the building is occupied. Provisions had to be made for evenings, weekends, and holidays when the internal heat gain is greatly reduced. Since the balance point of the building is 11°F, there would be excess heat during occupied periods at any time when the outdoor temperature exceeded this value. To avoid wasting heat, a scheme had to be devised to store the excess heat for use during unoccupied

periods. Tom, Bill Hennum and Jack Gruitt met and decided it would be desirable to store the excess heat in a water tank. Excess hot condenser water, not required for immediate heating, would be used to heat water in a reservoir. They explored many possibilities of providing ample storage capacity including underground commercially-fabricated steel tanks, specially built concrete reservoirs, and even approached a railroad company with the possibility of utilizing some surplus railroad tank cars. The expense involved in providing these underground storage facilities seemed to be a serious obstacle in putting the all-electric heating and cooling system together. They all became a little discouraged as it appeared they would not be able to utilize the surplus heat and would find it necessary to reject this heat either to a cooling tower or a spray pond.

Mr. Hennum, in an offhanded manner, mentioned one day that the plant had a 150,000 gallon underground concrete storage tank as a reservoir for their fire sprinkler system. The capacity was larger than necessary but Tom and Jack immediately seized upon this remark and decided that the tank was located close enough to the new building to extend piping from the mechanical room. The Fire Underwriters were approached for permission to use the tank for heat storage purposes and approval was given.

For the moment it appeared all problems were solved, but then Bill began to worry that with 125°F water, there would be a possibility of creating thermal cracks in the concrete. Tom analyzed this aspect and concluded the thermal stresses would not be significant. He also explored the possibility of adding insulation to the tank to reduce thermal losses through the walls of the tank and, again, he found the tank to be adequate.

According to Jack Gruitt, "The road I was travelling was not all smooth at this point because my competitor, the New Jersey Natural Gas Company, in conjunction with a manufacturer of compressor equipment, had entered the picture. They proposed that the compressor equipment be driven mechanically by an internal combustion engine fueled with natural gas. To add insult to injury, they also proposed a 'total energy system' with an electric generator to provide on-site generation powered by an internal combustion engine from which hot water off the cooling jacket and heat recovery from the exhaust could be utilized for space heating requirements. Another proposal was to run a 500 KW motor generator set to shave peak electrical demands during the day. However, Bill Hennum insisted that the 'total energy system' have back-up from Jersey Central Power

and Light Company in the event of a malfunction in the on-site generation equipment. The cost of stand-by service, added to the operating and maintenance expenses of the on-site equipment, made it economically unattractive."

Jack continued, "Of course, it was always possible to revert to a conventional system using a fuel-fired boiler to provide supplemental heat. A careful economic evaluation was prepared on a straight BTU-for-BTU basis, and the all-electric system held a decided advantage over either gas or oil as fuels. This point is particularly significant from an electric utility standpoint because it is the first time, in our experience, that we had become competitive on a straight BTU-for-BTU basis. One thing that made this possible was the coefficient of performance on the compressor equipment of approximately 4.0; in other words, for every unit of electrical energy expended, four units of heat are obtained. As you know, one kilowatt hour of resistance heating would provide only one unit of heat, or 3413 BTU. In order to prove just how little supplementary heat would be required during the heating season, I went to the extent of preparing a computer analysis of temperature readings taken at one of our dispatch centers close to the EAI building. Hourly temperatures for three years, 1960, 1961, and 1962, were the input to the program. The output was such that we could establish the number of hours and percentages in each five degree temperature range from -5 to 91°F. In our studies, we found that the temperature would fall below the occupied balance point of the building for less than 30 hours per year. (Figure 2B in the Appendix summarizes this information.) These few hours could not justify the installation of a fuel-fired boiler, chimney, and auxiliary equipment."

DESCRIPTION OF THE SYSTEM

Air Handling System

As mentioned in Part A, the design of the lighting and air handling system for the EAI administration building was a co-development project of the Barber-Colman Company of Rockford, Illinois, and the Day-Brite Lighting Division of Emerson Electric Company of St. Louis.

Day-Brite's "Clymatron" unit (shown in Figure 3B) is responsible for lighting, air return and heat transfer. Slots provided in the flanges of the fixture permit room air to return through the lamp compartment, picking up the heat generated from both lamps and ballasts and discharging to the plenum formed by the space above the hung ceiling. Air passing through the fixtures picks up about 82%

of this heat, preventing it from entering the space. Some heat is transferred back through the ceiling so that a net of about 65% of the heat from lights is kept from the room.

To handle the air supply, twelve fan and coil units are used as follows:

1. A fresh air makeup fan and dehumidifying coil supplies outdoor air to all air handling units in the building.

2. A central exhaust fan provides exhaust capacity for the majority of exhaust requirements for the building. As mentioned previously, this unit is equipped with a coil to be used as part of the fresh air heating system in winter.

3. On each floor above grade, there are four handling units. One supplies conditioned air to the interior of the building through ceiling diffusers and the other three supply conditioned air to the perimeters of the building.

4. Below grade offices are supplied by another air handling unit.

5. The cafeteria, below grade, is supplied by a single air handling unit through a system of ductwork.

Air is distributed to the first and second floor ceiling diffusers through 42 Barber-Colman induction units, providing 42 separately controlled zones in the exterior of the building. They operate as follows: when full cooling is required in a zone, primary conditioned air flows undisturbed into the space. Upon reduction in cooling requirements due to decrease in room temperature, the primary air is throttled, passing through a jet. Secondary air dampers open and induce warm plenum air into the unit to provide the desired mixed air temperature. At all loads, a constant quantity of air is admitted to each zone. The quantity of fresh air delivered to the interior of each floor is also maintained constant by means of a damper in the air handling unit.

Heating and Cooling System

The heating and cooling system can best be described by beginning with a standard chilled water system and then adding items to complete the system. Figure 1 shows a basic chilled water cooling system which supplies chilled water

to air handling units. In this case, a spray pond is used to cool the condenser water. A primary, secondary pumping system--chilled water loop, chilled water supply and return--is used for chilled water. This creates a more flexible pumping system, the desirability of which will be evident later.

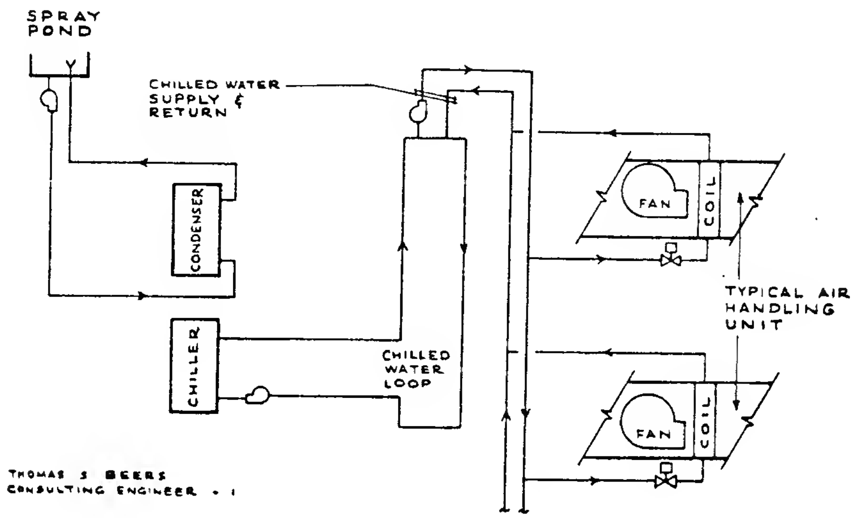


Figure 1

Chilled water is controlled through the coils of the air handling units by modulating valves--adequate for controlling sensible cooling load but poor for humidity control. However, in the EAI building, all ventilating air is introduced through a central fan and chilled water coil. About 95% of the dehumidification for the entire building is accomplished here and, as a result, the other coils may be throttled with impunity.

In Figure 2, hot water piping and pumping have been added between the condenser and the coils in the air handling units so that each coil may draw hot or chilled water on demand. During the heating season, instead of rejecting hot condenser water to the spray pond, the spray pond is valved off and hot water is pumped to the air handling units requiring heat. At the same time, the supply of chilled

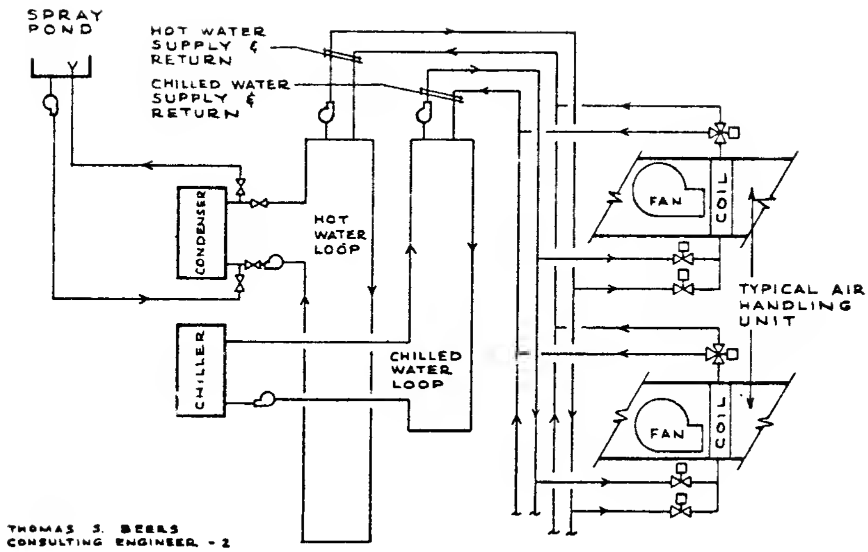


Figure 2

water is maintained to those units requiring it. Spray pond and system water are not mixed and a primary-secondary pumping system is also used for hot water. Obviously a system such as this will operate only when the cooling and heating loads balance--thus the need for a storage tank.

In Figure 3 on page 8, a storage tank and connecting piping are added, solving the problem of an exact cooling, heating balance. Excess heat, in the form of hot water, can be stored in this tank.

During unoccupied periods--night, holidays, weekends--the cooling load is zero and heating load is maximum. Under these conditions, the chiller is shut down and hot water is pumped from the storage tank to supply heat. The amount of useful heat available in the tank depends upon previous operation. Obviously, if the building were unoccupied for a sufficiently long period, the water temperature will drop below the useful point.

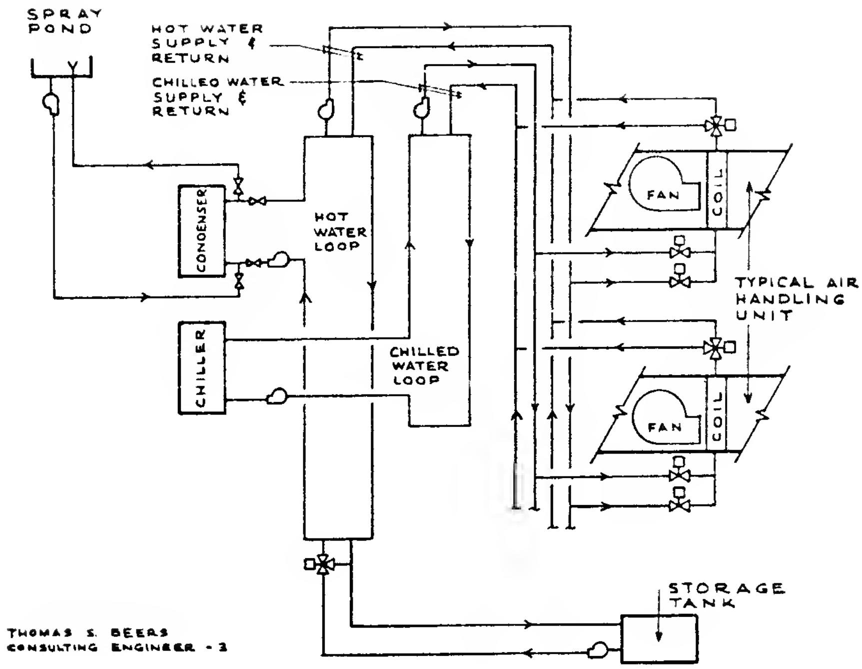


Figure 3

To handle this problem, a connection between the chilled water loop and the storage tank is added in Figure 4. When

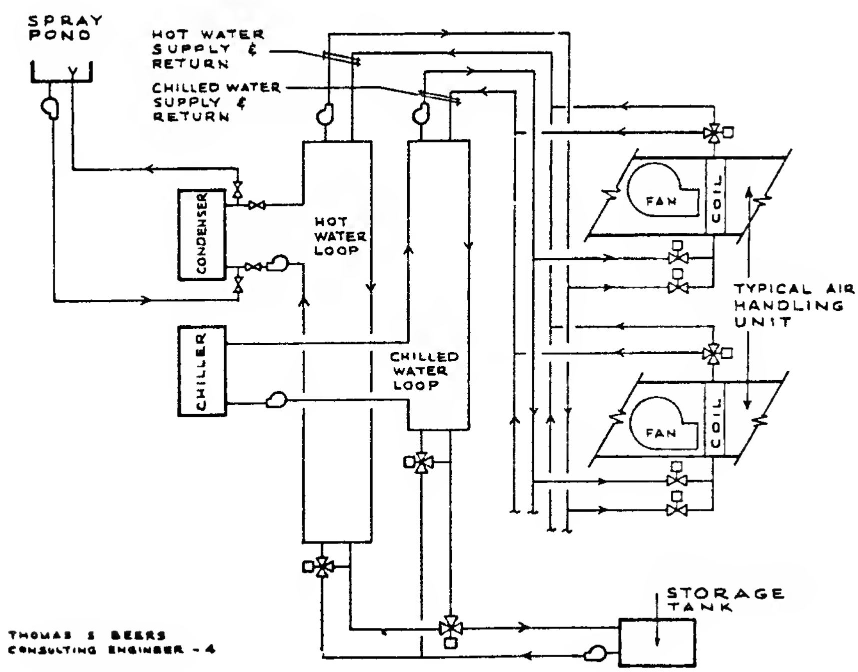


Figure 4

the tank temperature drops below the useful point, this connection makes possible the circulation of water into the chilled water side of the compressor. When the compressor is started, it operates as a heat pump with the storage tank as a source of heat. In this manner, useful heat may be extracted from the tank down to the point where the water is as low as 40°F. The amount of heat available in this mode is enormous. A 60°F **excursion** from 100°F to 40°F provides 75,000,000 BTU, not including the power input to the compressor. This would handle the building's heat needs for almost two days at 0°F outside temperature.

Two more additions are necessary to make the system complete. In Figure 5 a heat exchanger is added for use **on** certain warm days during the heating season. There will

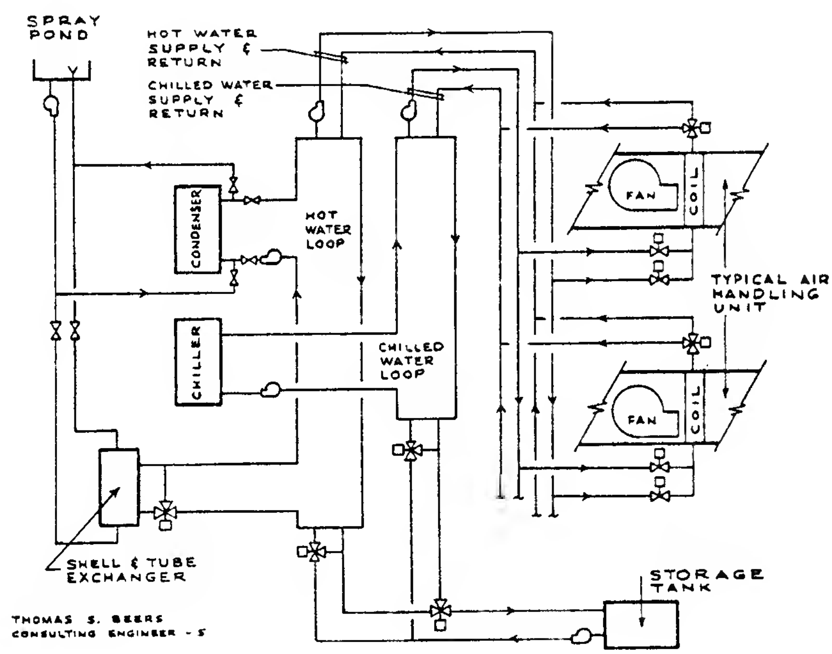


Figure 5

be times, on warm days, when the storage tank is loaded with hot water and the heat rejected by the condenser exceeds the building's requirement. Consequently, this heat must be wasted.

To accomplish this, a shell and tube heat exchanger has been added connecting the hot water loop to the spray pond. This enables heat to be diverted to the pond as required. Also, an electric resistance heater (not shown in the figure) was installed in a 300 gallon tank for use during a prolonged spell of very cold weather or during equipment failures.

The previous discussion dealing with the storage tank was concerned primarily with operations during the heating season. The storage tank can also be used to advantage during the cooling season to store chilled water. The compressors will be operated and chilled water stored at night for use the following day. This reduces daytime load on the compressors and gives two advantages. First, peak power demands normally involve a separate charge known as a "demand charge." Daily peak power requirements for the EAI facility are more or less coincident with peak cooling requirements; therefore, the more the compressors are used at night, the lower is the peak demand and, hence, power costs.

Second, less installed compressor capacity is required. As a result of this storage utilization, there was a reduction of 200 tons in compressor capacity--a very significant capital savings.

Figures 4B to 8B in Appendix B illustrate how the system works under varying seasonal and temperature conditions.

OPERATION

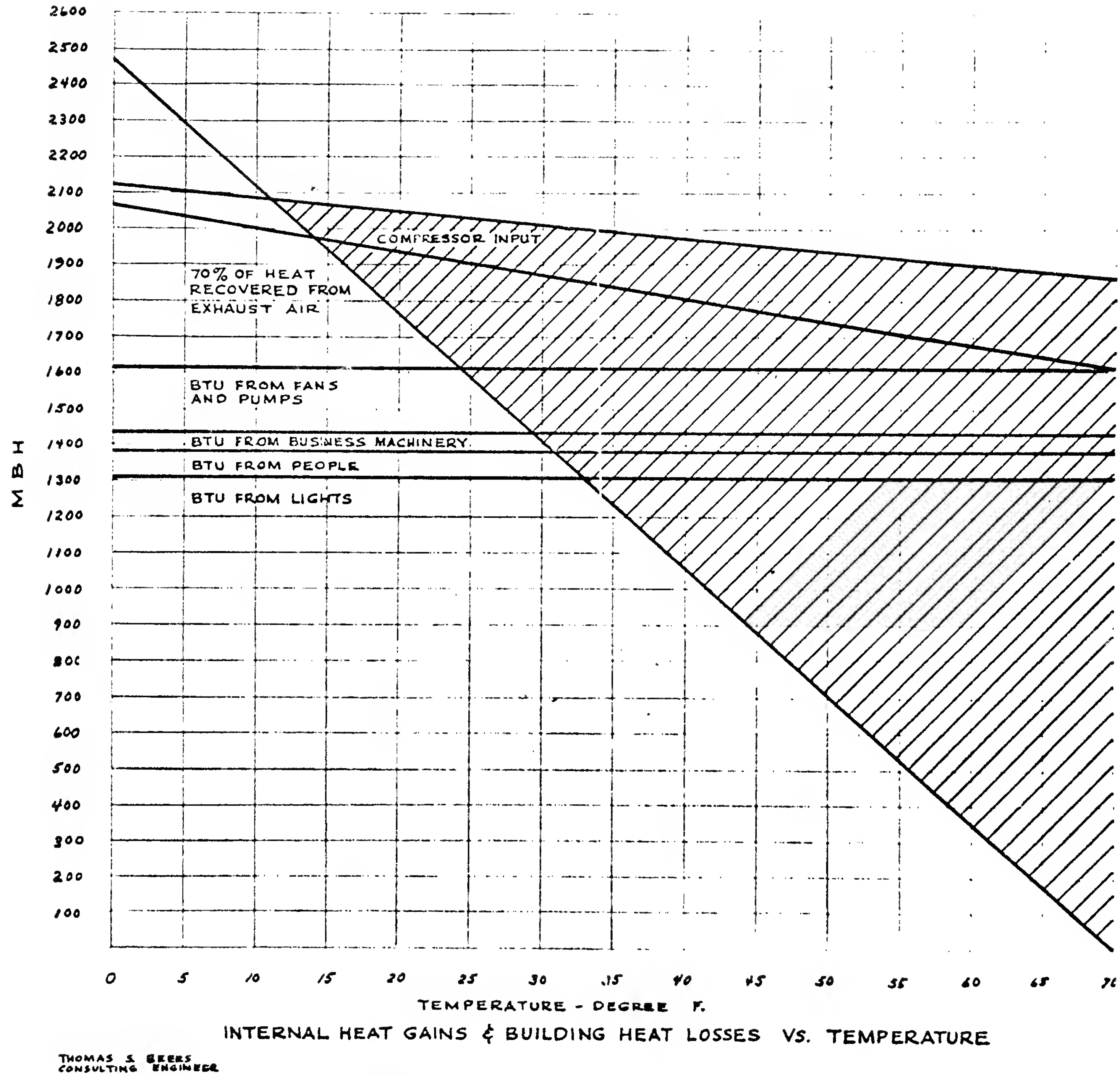
The building was put into service in November 29 1964. The operating results to date have exceeded the design expectations. This is due primarily to EAI installing more computer equipment, and therefore internal load, than originally planned. The balance point of the building at present is below 10°F.

A record has been kept of operating and maintenance costs. Appendix B also contains letters to Mr. Bill Hennum from Jack Gruitt and Tom Beers dealing with operating costs. In addition, a memo by Jack Gruitt concerning operating and maintenance procedures is included.

The results of the records indicate a very significant reduction in operating costs compared to conventional systems. To date, the electrical resistance heater has been in operation on only one occasion; this was due to a breakdown in the storage tank pump.

In 1965, Mr. Thomas S. Beers was given an award by Actual Specifying Engineer for "outstanding innovation and achievement in advancing the science of mechanical engineering for the benefit of mankind" for his role in the design of the EAI building.

APPENDIX B



ADMINISTRATION BUILDING LOAD CURVE

Figure 1B

AVERAGE NUMBER OF HOURLY TEMPERATURE READINGS TAKEN IN ALLENHURST - INCLUDING 1960-61-6

Compiled by: J. F. Gruitt
Jersey Central Power & Light Co.
April 15, 1963

Temp. Range F.	Average Hours Per Year	%	Cumulative Totals	Cumulative % of Heating Season
- 5 - - 1	1	-	1	-
0 - 4	6	0.1	7	0.1
5 - 9	15	0.3	22	0.3
10 - 14	68	1.2	90	1.6
15 - 19	139	2.5	229	4.1
20 - 24	207	3.7	436	7.8
25 - 29	352	6.3	788	14.1
30 - 34	543	9.7	1331	23.8
35 - 39	777	13.8	2108	37.6
40 - 44	766	13.6	2874	51.2
45 - 49	718	12.8	3592	64.0
50 - 54	635	11.3	4227	75.3
55 - 59	685	12.2	4912	87.5
60 - 64	706	12.5	5618	100.0
Heating Season Totals	5618	100.0	-	Cumulative % of Cooling Season
65 - 69	899	28.6	3142	100.0
70 - 74	932	29.7	2243	71.4
75 - 79	750	23.9	1311	41.7
80 - 84	349	11.1	561	17.8
85 - 89	160	5.1	212	6.7
90 - 94	48	1.5	52	1.6
95 - 99	4	0.1	4	0.1
Cooling Season Totals	3142	100.0	-	-
Annual Totals	8760	-	8760	-

Seasons	%	Hours
Heating	64.1	5618
Cooling	35.9	3142

Figure 2B

INSULATED DUCT WORK AND HEAT TRANSFER LIGHTING FIXTURES ARE SHOWN IN THE CEILING OF ELECTRONIC ASSOCIATES INC. NEW ADMINISTRATION BUILDING. Figure 3B

Summer Night: Storing Cold Water

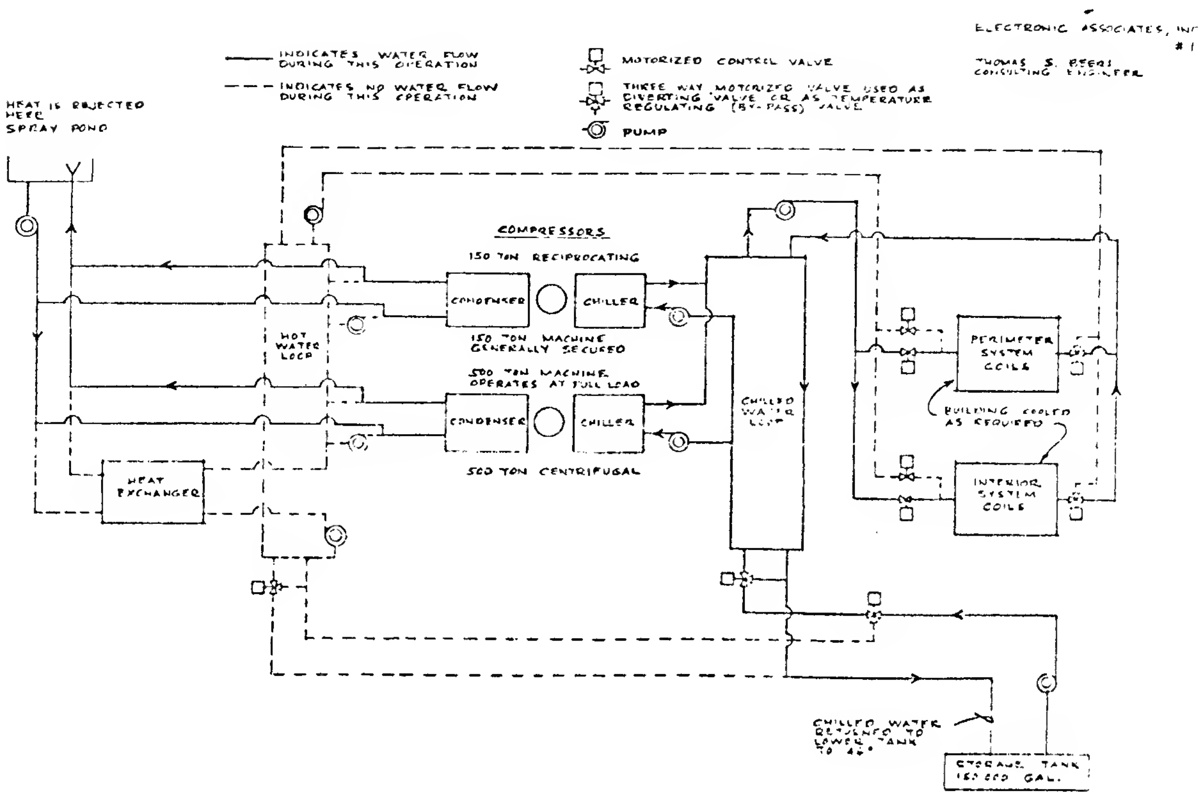


Figure 4B

Summer Day: Using Stored Cold Water

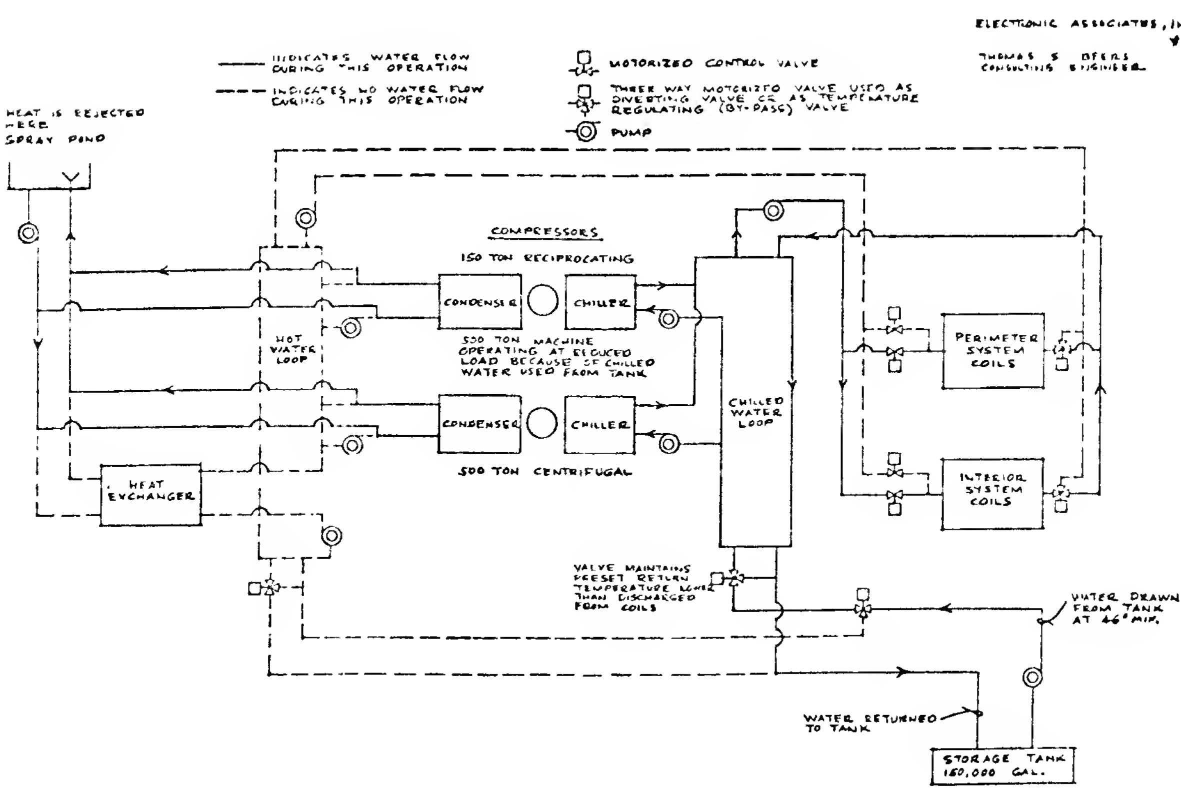


Figure 5B

Winter: Normal Heating

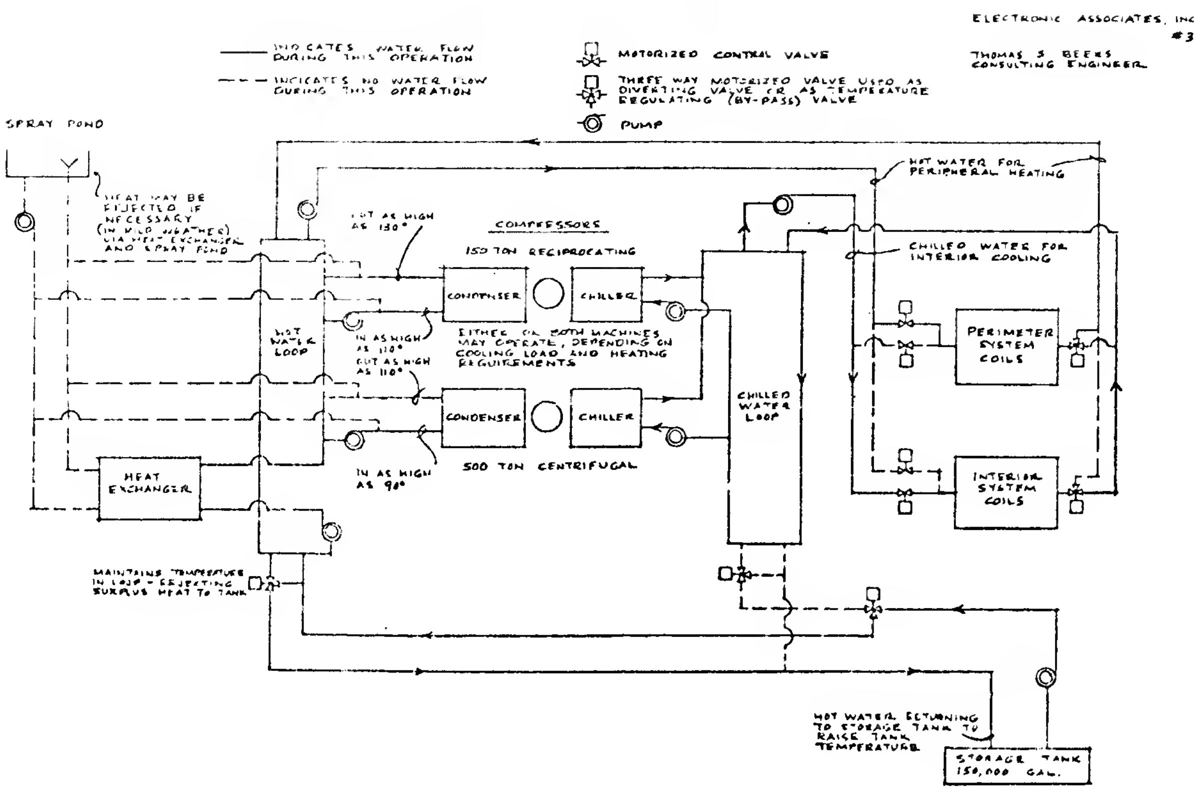


Figure 6B

Winter: Night & Weekend Heating, Mild Weather

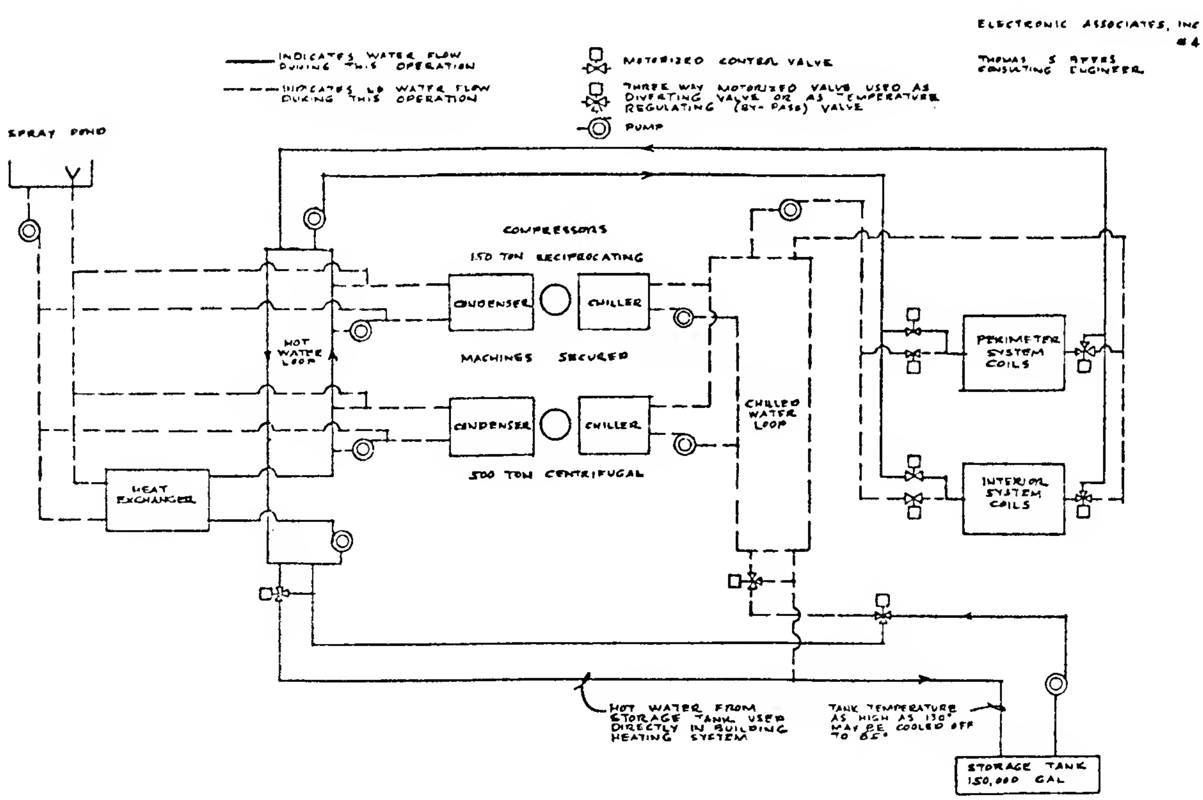


Figure 7B

Winter: Extreme Weather Heating (tank temperature too low for direct use)

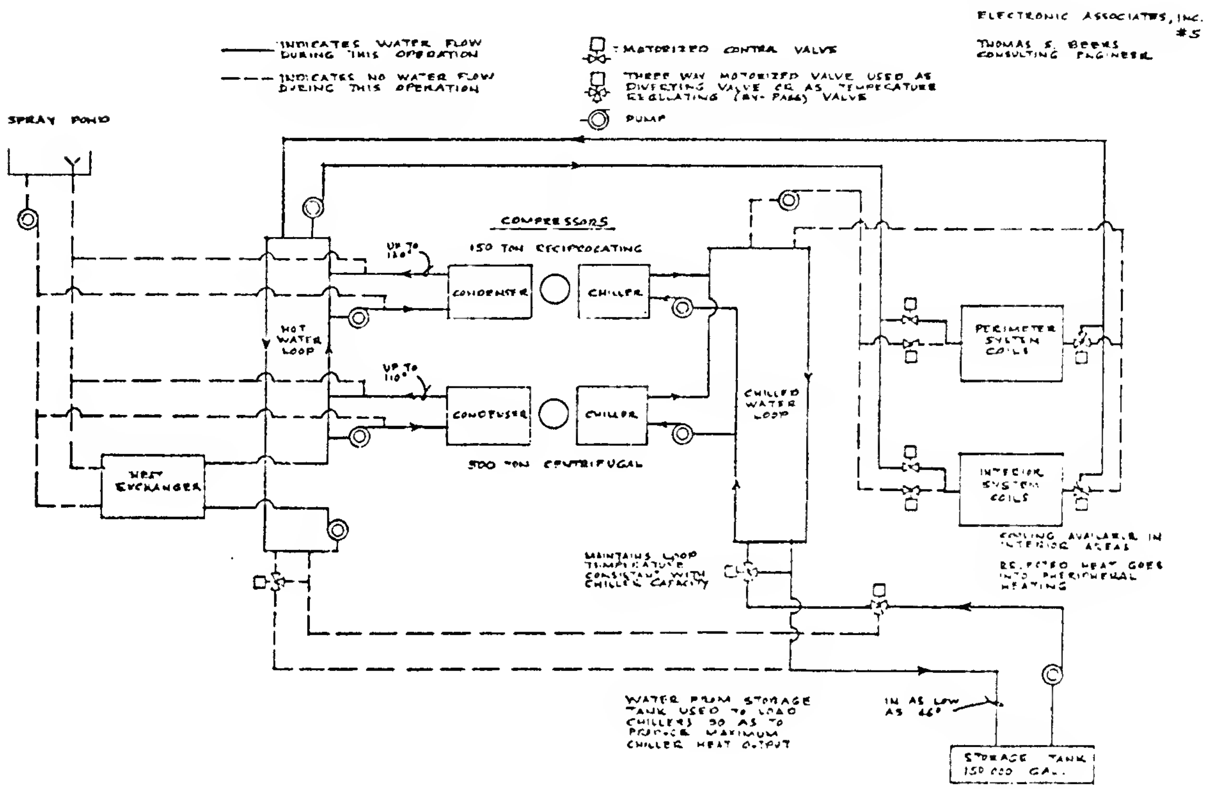


Figure 8B

EXHIBIT 1B

August 1, 1968

Electronic Associates Inc.
185 Monmouth Parkway
West Long Branch, N. J.

Attention: Mr. William Hennum
Plant Engineer

Dear Bill:

Last week I had the occasion to review some of the test metering data which we compiled during the period, November 1965 to October 1966. I thought perhaps you would be interested in the results.

The figures listed on the attached sheet are for proportioned total energy input to the "A" building. In other words, the amount of energy that has gone toward heating and cooling of other buildings has been extracted from the total. The second column indicates the KWH consumption for the heating and cooling system with auxiliaries included for the "A" building only. In order to arrive at a dollar value, I took the average cost of .0113¢ per KWH and multiplied it by the KWH charge to the heating and cooling per month. The .0113¢, as you know, includes both the demand and KWH energy charges. This figure represents the actual average cost of the billing during the period involved and does not reflect the savings that could be realized had you received the benefit of Rider J, our all-electric rate.

In order to clarify the above, I have shown, in the attached tabulation, the method of calculation I used to derive my demand and KWH figures for each month, using November 1965 as an example. It is interesting to note that the cost of operating the heating and cooling system in the "A" building amounted to 10.4¢ per sq. ft. per year including auxiliaries. This, I believe, is a significant figure to keep in mind for it points up the inherent efficiency and economy in the recovery and heat storage system. Our competition in the fossil fuel business would gladly accept 10¢ per sq. ft. just to heat a building exclusive of cooling or auxiliary cost.

It is impossible to attest 100% to the accuracy of the attached figures because they are directly connected to the accuracy of the data which was compiled through our test metering. November 1965 to October 1966 represents the best

Electronic Associates Inc. August 1, 1968

and most complete data that was compiled during the approximate two years in which the test metering equipment was installed.

Should you have any questions, please feel free to call.

Very truly yours,

JFG:SR

JOHN F. GRUITT
Space Conditioning Specialist

CC: T. S. Beers
Consulting Engineer

EXHIBIT 2B

EAI Administration Building Only
Test Meter Results

	("A" Building Proportioned Input)		Heating and Cooling (Aux. Incl.)	
	KW	KWH	KWH	Amt. (.0113 aver./KWH)
Nov. '65	955 **	337,246 *	83,814	$ 947.10
Dec.	632	289,512	63,878	721.82
Jan. '66	696	295,838	77,727	878.32
Feb.	682	327,530	64,178	725.21
Mar.	759	255,709	71,613	809.23
Apr.	846	270,851	57,005	644.16
May	833	262,734	50,222	567.51
June	924	302,545	95,374	1,077.72
July	840	278,970	95,274	1,076.60
Aug.	801	263,082	93,919	1,061.28
Sept.	914	296,086	63,374	716.13
Oct.	841	250,194	53,851	608.52
Totals		3,430,297	870,229	$ 9,833.60

Cost per sq. ft. per yr. = 10.4¢

* Example:

Nov. '65 Total system KWH (aux. incl.) = 149,018 KWH

"A" building KWH (aux. incl.) = -83,814

Proportioned to other buildings = 65,204 KWH

Total energy input to "A" building = 402,450 KWH

-65,204

337,246 KWH

** Demand (evolved by KWH use of demand basis)

Nov. '65 Total = $\frac{402{,}450 \text{ KWH}}{1139.5 \text{ KW}}$ = 353.2 KWH use of dem.

"A" building = $\frac{337{,}246}{353.2}$ = 954.8 or 955 KW (Proportioned) **

EXHIBIT 3B

Original to Mr. Hennum
carbon copy: Mr. Kellonyi
Mr. Werner
Mr. Tull

ECL 196B

February 12, 1965

Electronic Associates, Inc.
Long Branch Avenue
West Long Branch, N.J.

Att: Mr. William Hennum

COPY

Dear Mr. Hennum:

As a result of the Kilowatt hour meter readings for the period December 30, through January 28, I have made a comparison between cost to operate conventional system and the system installed in your plant. Since btu meters, etc., are not yet installed, it was necessary to make certain "guesstimates" which I think you will agree are quite logical and based on your logs of operation. I have not included the very small amount of power which went into both the resistance heat and the centrifugal machine for the following reasons:

1. Power input to the centrifugal machine was basically used only to test the equipment, and not necessarily for the operation of the plant.

2. Power input to the resistance heat was also in the same category.

I feel that the figures which result are quite conservative, especially as regards the comparison with "free cooling." As you are aware, the vast majority of free cooling installations require, at some point, a considerable amount of "re-heat." Cost of fuel for re-heating purposes was completely omitted in this analysis.

Very truly yours,

THOMAS S. BEERS

TSB:jh

C O P Y

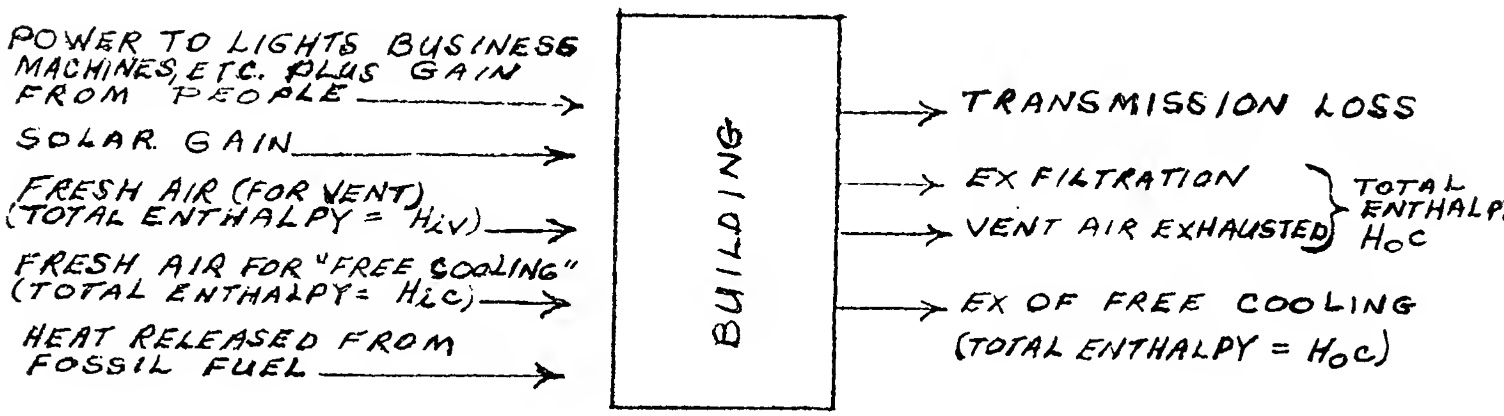
ECL-196B

THOMAS S. BEERS
CONSULTING ENGINEER

38 BURROWES PLACE
RED BANK, N.J.

USING FUEL OIL & FREE COOLING

HEAT IN — HEAT OUT



HEAT RECOVERY & MECHANICAL COOLING

HEAT IN — HEAT OUT

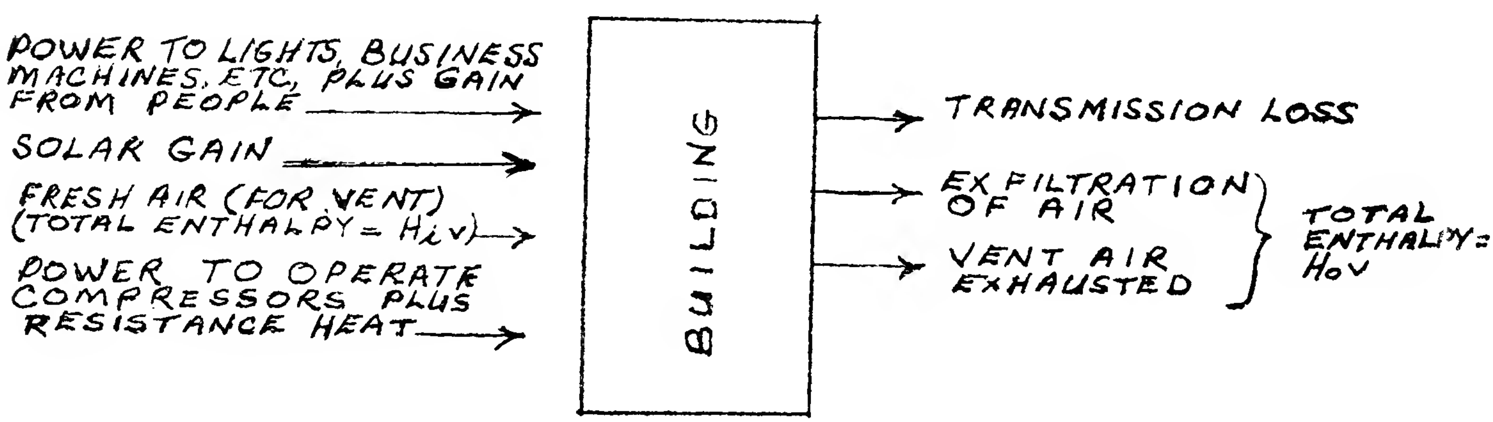


EXHIBIT 4B

THOMAS J. BEERS
CONSULTING ENGINEER

38 BURROWES PL.
RED BANK, N.J.

ECL 196B

HEAT IN EQUALS HEAT OUT

ALL ITEMS BELOW EXPRESSED IN BTU:

LET POWER TO LITES, BUSINESS MACHINES, & GAIN FROM PEOPLE = P_L

LET SOLAR GAIN = S

LET TOTAL ENTHALPY OF VENTILATION AIR ENTERING BUILDING = H_{iv}

LET TOTAL ENTHALPY OF AIR FOR FREE COOLING = H_{ic}

LET HEAT RELEASED FROM FOSSIL FUEL = O

LET POWER INPUT TO COMPRESSOR PLUS RESISTANCE = P_{c+R}

"HEAT IN" ITEMS

LET TRANSMISSION LOSSES = T

LET TOTAL ENTHALPY OF EXFILTRATION AIR
LET TOTAL ENTHALPY OF VENT. AIR EXHAUSTED
} COMBINED = H_{ov}

LET TOTAL ENTHALPY OF "FREE COOLING" AIR EXHAUSTED = H_{oc}

"HEAT OUT" ITEMS

EQUATION FOR FOSSIL FUEL & FREE COOLING

HEAT IN = HEAT OUT

OR

$$P_L + S + H_{iv} + H_{ic} + O = T + H_{ov} + H_{oc}$$

$$O = T - P_L - S + \underbrace{H_{ov} - H_{iv}}_{= \Delta H_v} \underbrace{+ H_{oc} - H_{ic}}_{= \Delta H_c}$$

ALWAYS POSITIVE DURING HTG. SEASON

$$O = T + \Delta H_v + \Delta H_c - P_L - S$$

SIMILARLY EQUATION FOR MECHANICAL COOLING & HEAT RECOVERY

$$P_{c+R} = T + \Delta H_v - P_L - S$$

BY DATE SUBJECT SHEET NO. OF
CHKD. BY DATE JOB NO.

THOMAS S. BEERS
CONSULTING ENGINEER

ECL 196B

38 BURROWES PL.
RED BANK, N.J.

DIFFERENCE IN BTU INPUT BETWEEN MECHANICAL COOLING - HEAT RECOVERY SYSTEM & FOSSIL FUEL FREE COOLING SYSTEM IS ΔH_c

ΔH_c = BUILDING COOLING REQUIREMENTS WHICH IS ALSO EQUAL TO COMPRESSOR COOLING LOAD EXCEPT FOR PERIODS WHEN COMPRESSOR IS "FALSE LOADED"

30,208 KWH ENERGY DEC. 30, TO JAN 28
PEAK KW DEMAND 172.8 KW ON SUNDAY JAN. 3,
COST OF OPERATION @ 1¢ AVG./KWH = \$302.08 TO HEAT & COOL

ASSUMING AVERAGE OPERATION @ 120°F. REFRIGERANT COND. TEMP. & CHILLED WATER @ 44°F.

FROM WORTHINGTON COMPRESSOR DATA AT ABOVE CONDITIONS
$\frac{144.8}{137.4}$ = 1.053 KW INPUT. PER TON OF REFRIGERANT

ASSUME 2,000 KW HRS. TO FALSE LOADING

30,208 - 2,000 = 28,208 KWH TO COOLING
OR $\frac{28,208}{1.053}$ OR 26,788 TON HOURS OF COOLING

26,788 X 12,000 = 321,000,000 BTU OF COOLING OR OF HEAT REMOVED FROM BUILDING

28,208 KWH X 3,413 = 96,273,904 BTU OF COMPRESSOR INPUT
HEAT OF REJECTION - 417,273,904 BTU AVAILABLE FOR HEATING OR SENT TO SPRAY POND IF EXCESS.

Y .... DATE .... SUBJECT .... SHEET NO. .... OF ....
KD. BY .... DATE .... JOB NO. ....

THOMAS S. BEERS

CONSULTING ENGINEER

ECL 196B

38 BURROWES PL.
RED BANK. N.J.

POWER COST TO COOL BUILDING =

28,208 KWH OR @ 1¢ – $282.

FUEL OIL WHICH WOULD HAVE BEEN USED AS A RESULT OF "FREE COOLING"

$$\frac{321{,}000{,}000}{(.75)(152{,}000)} = 2{,}815 \text{ GAL. @ } 8¢ = \$225.$$

BTU AVAILABLE HEATING FROM PREVIOUS 417,273,904

ASSUMING 75% OF ABOVE ACTUALLY USED. OIL EQUIVALENT EQUALS:

$$\frac{(417{,}273{,}904)(.75)}{(.75)(152{,}000)} = 2{,}745 \text{ GAL. @ } 8¢ = \$219.60$$

FREE COOLING & OIL FIRED

TOTAL OIL COST @ 8¢/GAL.
HEAT & COOL

225
219
$444.

HEAT RECOVERY & MECH. COOLING

TOTAL ELECTRIC COST
TO HEAT & COOL

$302.08

MECH. COOLING & OIL FIRED

POWER COST TO COOL BUILDING — $282.00
OIL COST TO HEAT BUILDING — $219.00
$501.00

SAVING OF "HEAT RECOVERY" SYSTEM OVER
"FREE COOLING" & OIL FIRED SYSTEM ———— $142.00

SAVING OF "HEAT RECOVERY" SYSTEM OVER
MECHANICAL COOLING & OIL FIRED SYSTEM ———— $199.00

THE FOLLOWING WAS NOT TAKEN INTO ACCOUNT IN ABOVE ANALYSIS BUT APPROXIMATES A "WASHOUT":

1- HEAT RECOVERY & MECH. COOLING – "STORAGE" PUMP MOTOR ASSUME @ 35 HP
AVG. INPUT KW INPUT = 30, HEAT RELEASE TO WATER 89,000 BTU

2- FOSSIL FUEL & "FREE COOLING" – APPROX. HP REQD. (MOTOR SIZE)
FOR FREE COOLING AIR FANS (2 RQD) FAN CFM
23,000 + 31,880 – 14,500 = 40,380 CFM
APPROX. 10 HP IN + 10 HP OUT = 20 HP
OIL BURNER & PUMP HP = 1½ HP
FUEL OIL HEATER = 1½ KW

JERSEY CENTRAL POWER & LIGHT COMPANY
NEW JERSEY POWER & LIGHT COMPANY

INTER-OFFICE MEMO

SUBJECT	Operating and Maintenance Procedures on the Space Conditioning System at EAI	LOCATION	Asbury Park
TO	R. H. Tull	DATE	November 22, 1967

As you may recall, you requested that I attempt to provide information on the maintenance and operating procedures at EAI for the report which you are in the process of preparing. I have had several conferences with Bill Hennum and John Merlander on the subject, and I wish to submit the following comments:

EAI has 2 men performing a dual function of operating and doing the maintenance work on machinery and equipment used for heating and air conditioning of the administration building and the third and fourth quadrants. These same 2 men also do some of the maintenance and repair work on other heating and air conditioning equipment throughout the rest of the plant when time permits. This includes maintenance on the fuel-fired heating system and individual air conditioning units throughout the original plant. In the summer months or the season requiring peak air conditioning performance, EAI works 2 eight-hour shifts from 7 A.M. to 11 P.M. In the winter months, only 1 man works from 7 A.M. to 3:30 P.M. His function is to start up equipment, check temperatures throughout the building, check the fan rooms, storage tank and pump house. He also monitors the chilled and hot water temperatures. Periodically, throughout the day, he continues to check on temperature and conditions throughout the various zones and areas. In between the above-mentioned duties, he performs whatever maintenance work is required on the machinery and equipment. A second man comes in at 9:30 A.M. and does either maintenance or repair work on the machinery and equipment, and works with the regular maintenance crew on other projects until 3 P.M. At that time, he returns to the machinery room and confers with the daytime operator, obtaining any information about happenings and events of the day in order that he can carry on the mode of operation and performs maintenance work until he sets up the equipment for the nighttime operation.

<u>Daily Operation Routines</u> -

Start up machinery as required to maintain control on temperatures.

Check all areas for ambient temperature including third and fourth quadrants.

Check all fan rooms for proper machine and equipment operation.

Take and record water temperatures every hour.

Check spray pond and pump pit for leaks and proper pumping, etc.

EXHIBIT 5B

ECL 196B

JERSEY CENTRAL POWER & LIGHT COMPANY
NEW JERSEY POWER & LIGHT COMPANY

INTER-OFFICE MEMO

SUBJECT EAI

LOCATION Asbury Park

TO R. H. Tull

DATE November 22, 1967

Check storage tank and pump pit for leaks and proper pumping, etc.

Continue to keep check on area ambient temperatures throughout the day.

Set up valving and pumps for operation of the storage tank.

Maintenance Routines -

Repair valves and controls

Tighten belts and check pulleys

Lubrication of equipment

Painting and clean-up

Change and replace air filters - there are 221 filters changed every month by the operators. Of these, 86 filters are in the administration building; the others are in the third and fourth quadrants.

Take water test and add chemicals as needed

Change oil in compressors

Make all necessary repairs to equipment, pumps and piping

Routine operations, checks and changes to the computer Q.C. areas

The operators start up the diesels and run them for one or two hours each week.

Routine maintenance on public address system located in control room

Routine check and operation of humidifiers on the ground floor

----

Breakdown of Operating and Maintenance Cost -

	ANNUAL
Salaries (unburdened)	$ 12,000
40% of time allocated for operating of equipment	4,800
43% of the above operating time charged to "A" building	2,064
60% of the time for maintenance and repair	7,200
43% of the above time for maintenance and repair charged to "A" building	3,096
Cost of maintenance materials to "A" building	1,000
Maintenance and operating cost to the "A" building (unburdened)	~~7,156~~ 6,160

ECL 196B

JERSEY CENTRAL POWER & LIGHT COMPANY
NEW JERSEY POWER & LIGHT COMPANY

INTER-OFFICE MEMO

SUBJECT EAI

LOCATION Asbury Park

TO R. H. Tull

DATE November 22, 1967

Since the system has been in operation, EAI has had various operating problems. Those which I can recall were as follows:

A freeze-up occurred due to a fault on the part of the operator who attempted to run the equipment without pumps in operation.

Another freeze-up occurred due to the fact that controls were set too low. According to EAI, the manufacturer originally made the setting on the controls, and should properly be considered a manufacturer's error.

A gasket was blown on the 150 ton reciprocal compressor, causing a motor burn-out. This was due to a bad filter and, according to EAI, should be considered as a manufacturing error.

The other incident that occurred since the start-up of equipment in November 1964 was a ground in the storage pump motor due to the failure of a sump pump in the pit, allowing water to rise, causing a mal function in the pump itself.

With the exception of the above, the system has run relatively free of any major problems, and those that did occur could be attributed to manufacturers' errors and lack of proper operating knowledge on the part of the personnel in charge of the system. These faults have since been rectified and, at the present time, the system is operating quite satisfactorily.

I trust the above will give you the necessary information you are looking for to be included in your report. Should you find that you require additional data, please advise.

Jack Gruitt
JOHN F. GRUITT
Space Conditioning Specialist

JFG:SR

CC: T. S. Beers
Consulting Engineer

BIBLIOGRAPHY

1. Beer, T. S., "Electronic Associates Inc.'s Administration Building," Actual Specifying Engineer, September, 1965, pg. 35.

2. General Electric Company, Publication TP-126, "Electrical Space Conditioning."

3. Industrial Construction, Technical Bulletin 110, "Heat-Light Concept Used in Industrial Building," December, 1964, pg. 26.

INSTRUCTOR'S GUIDE

CASE TITLE: The Space Conditioning System for Electronic Associates, Inc.

RELATED UNDERGRADUATE CURRICULUM AREAS:

1. Thermodynamics.
2. Heat Transfer, Thermal Environmental Engineering.
3. Engineering Analysis.
4. Engineering Economics.

SYNOPSIS: Quoting from one of the principals in this case study, "The heating and cooling system for the Electronic Associates, Inc. administration building, in my opinion represents nearly the ultimate in conservation of energy." The design of the system is such that heat recovery and storage--the "heat-of-light" principle--are utilized within an all-electric concept without building modifications or extra insulation.

The electric utility representative, Jack Gruitt, captured the imagination of the EAI engineer, Bill Hennum, by mentioning the possibility of utilizing the waste heat from the building lights. Although Jack was unfamiliar with the details of the concept he contacted several manufacturers who demonstrated the concept.

Mr. Beers, the consulting engineer for the project, designed a very unique system which should indicate to the reader the opportunities for the exercise of creativity and engineering judgment in this field.

QUESTIONS FOR THOUGHT AND DISCUSSION:

1. What is the cost of energy on a BTU/penny basis in your locale for #2 and #4 fuel oil, natural gas, and electricity? Assume 70% boiler efficiency for oil and gas furnaces.

2. Discuss the ecological considerations of #1.

3. Discuss the possibilities of utilizing presently wasted sources of heat in homes.

4. What would be your recommendation for the heating, ventilating and air conditioning system for the EAI building? Refer to the data sheet on page 2A.

After reading Part B:

1. Why did Tom Beers decide to use mechanical refrigeration rather than "free cooling" and conventional heating?

2. Discuss the heat storage system and its use during evenings and weekends.

3. Describe and discuss the air handling system. How is temperature maintained in each zone?

4. Discuss the heating and cooling system. Describe the summer and winter operations during occupied and unoccupied periods.

5. Clearly identify the times during the project when engineering judgment was exercised.